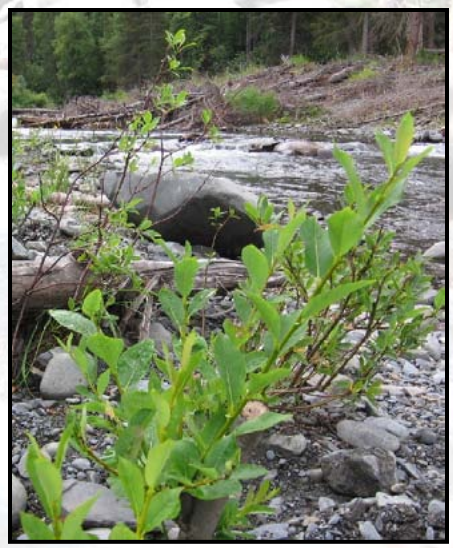
Resurrection Creek Stream and Riparian Restoration Project



Stream Channel and Vegetation Monitoring Report, 2005 through 2008

USDA Forest Service
Chugach National Forest

January 2009

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Seward Ranger District

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Summary

The Resurrection Creek Stream Restoration project was implemented in 2005 and 2006, with project area revegetation continuing through 2008. Stream channel morphology and vegetation have been monitored in 2005, 2006, 2007, and 2008. This report compiles the 2008 data and summarizes the 4 years of monitoring data and the short-term response of the project area to the restoration.

Each of the project objectives established prior to the implementation of this project were fully or partially accomplished. These included variables that quantify channel pattern, channel profile, side channels, aquatic habitat, and riparian vegetation. While the target values may not have been met in all cases, the intent of each objective was met through restoration.

The response of the project area in the 3 years following restoration represents the short-term response to restoration. While numerous changes can occur in this period as the morphology and vegetation adjusts to the new conditions, no major channel changes have occurred on Resurrection Creek or its side channels, and vegetation growth in the riparian area has occurred as expected. Data from established channel cross sections show little change in channel dimensions and provide baseline data for evaluating long term changes. Evaluations of vegetation growth show that both the planted vegetation and the natural regeneration have been highly successful in areas where soil was spread onto the floodplains. Photo points primarily show changes that would be expected in the project area and provide a baseline for evaluating long term changes.

This 4-year monitoring effort highlights the fact that the new stream channels in the project area were constructed successfully, and successful techniques were used to reestablish the riparian vegetation. However, this report also highlights some aspects of the project that could have been implemented better and provides recommendations for future restoration projects.

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1 INTRODUCTION

The Chugach National Forest conducted large-scale restoration of a 1-mile reach of Resurrection Creek in 2005 and 2006, with re-vegetation work continuing in 2007 and 2008. The project area is located about 5 miles south of Hope, Alaska (**figure 1.1**). This project restored a 1-mile reach that was highly impacted by historic placer mining to its natural conditions by redistributing large tailings piles, constructing a series of meanders in the main channel, re-constructing the floodplains, and creating pool-riffle sequences and side channels with abundant and varied aquatic habitat.

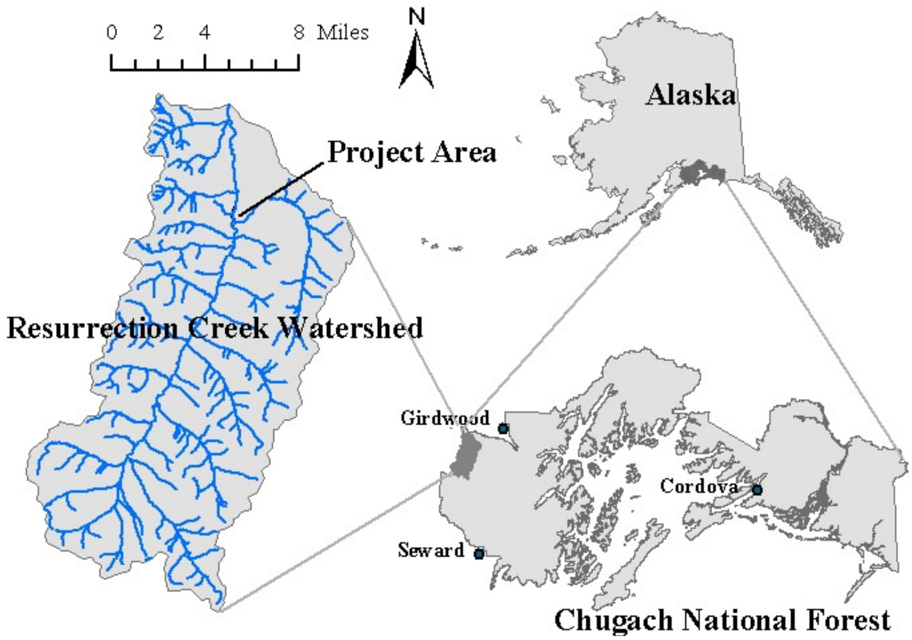


Figure 1.1: Location of the 2005-2007 Resurrection Creek Restoration Project.

1.1 Project Objectives

The specific quantitative objectives of the project include the following, as adapted from the pre-restoration analysis by Bair et al. (2002):

- *Floodplains*: Increase the amount of available floodplain for the main channel and side channels by increasing the entrenchment ratio (the ratio of the floodprone width to the bankfull width) from about 1:1 to greater than 6:1.

- *Channel pattern*: Reconstruct the main channel of Resurrection Creek from a straight channel to a meandering channel by increasing the channel length by about 15% and increasing the sinuosity from 1.1 to 1.4.

- *Channel profile*: Decrease the average main channel slope from about 1.5% to 1.1%. Construct pool-riffle sequences in the main channel by constructing pools on the outsides of the bends, increasing the number of pools (with residual depth greater than 1 meter) per river mile from about 3 to 23.

- *Side channels*: Construct varied side channel habitat throughout the reach and increase the percentage of the total Resurrection flows that is in these side channel flow from <1% to 5-20%.

- *Aquatic habitat*: Increase the amount of available spawning gravel from 160 to about 2000 yd^2 per river mile, and increase the amount of large in-stream wood from 8 to 330 pieces per river mile.

- *Riparian vegetation*: Restore topsoil to at least 80% of the floodplain, increase coarse woody debris on the floodplain from 16 to about 120 pieces per acre, and increase snags from 2 to 10 snags per acre. Decrease overstocked riparian tree densities, restore tree composition (50% spruce, 40% cottonwood, and 10% birch and hemlock), and reestablish ground cover.

1.2 Background Documentation

Numerous documents provide background information on this project, as well as past monitoring efforts. These documents are available at the Chugach National Forest Supervisor's Office, Anchorage, Alaska, and many are located on the Chugach National Forest website at http://www.fs.fed.us/r10/chugach/. These include the following:

- *Resurrection Creek Stream and Riparian Restoration Project Final Environmental Impact Statement (FEIS)* (USDA Forest Service, 2004)

- *Resurrection Creek Watershed Association Hydrologic Condition Assessment* (Kalli and Blanchet, 2001)

- *Resurrection Creek Landscape Analysis* (Hart Crowser, 2002)

- *Resurrection Creek Stream Channel and Riparian Restoration Analysis River Kilometer 8.0-9.3* (Bair et al., 2002)

- *Resurrection Creek Restoration 2005 Channel Morphology Monitoring Report* (MacFarlane, 2006)

- *Resurrection Creek Restoration 2006-2007 Channel Morphology and Vegetation Monitoring Report* (MacFarlane, 2007)

- *2007 Summary Report- Resurrection Creek, Seward Ranger District (Chugach NF) - Habitat and Juvenile Salmonid Assessment and Comparison Project (Martin, 2007)*

1.3 Project History

This project was accomplished over the course of 4 years. A comparison of aerial photography from before and after project completion is shown in **figure 1.2**. Also shown are names and locations of various channel features described in this report.

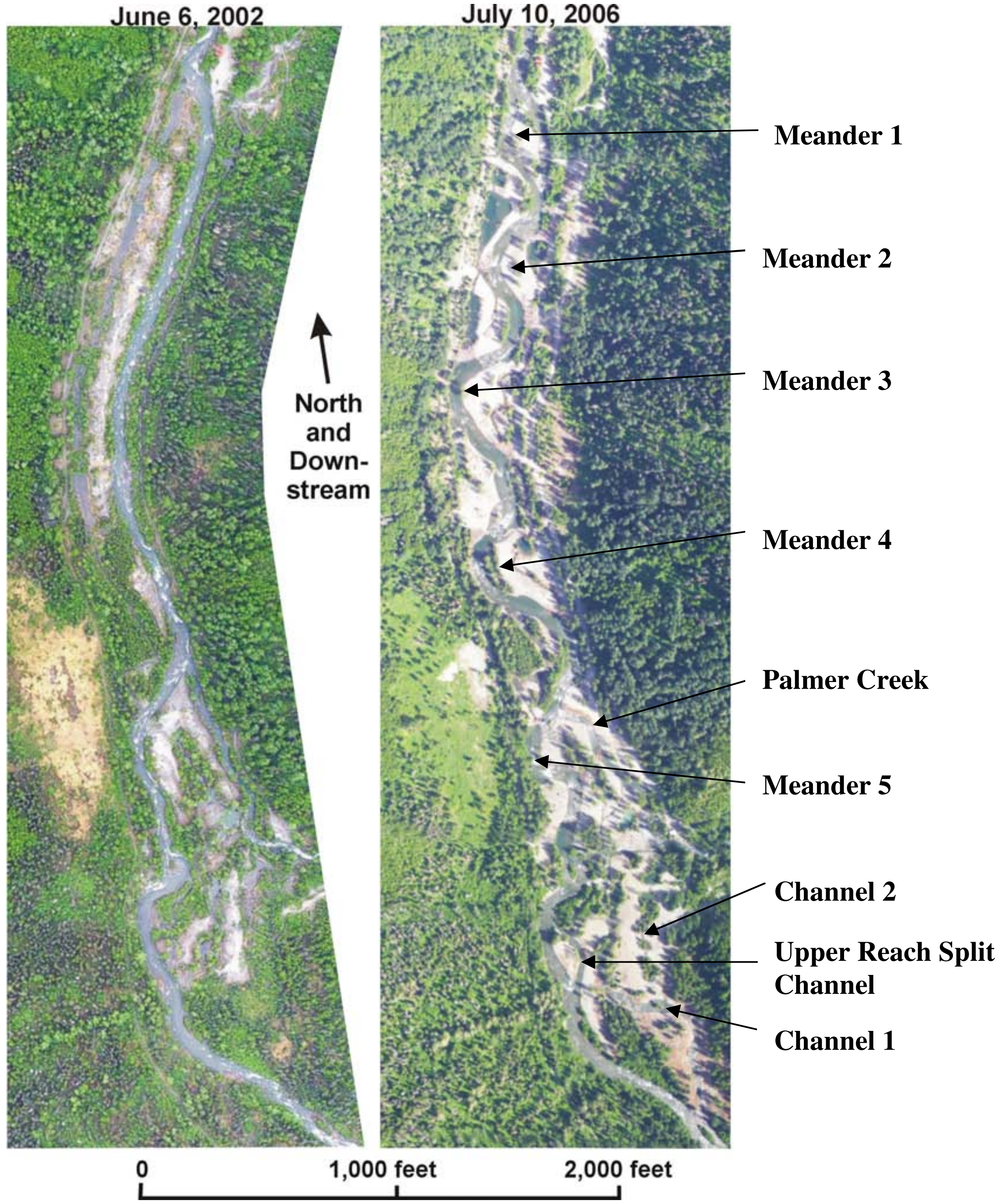


Figure 1.2: Resurrection Creek project reach aerial view before restoration (left) and after restoration (right), and names of features described in this report.

Tasks completed in 2005: The Final Environmental Impact Statement (FEIS) for this project was completed in November 2004 (USDA Forest Service, 2004), and permits were in place by early May 2005. The first season of construction occurred from mid-May to mid-July 2005. The following tasks were accomplished in 2005:

- Redistributed about 120,000 cubic yards of tailings piles and developed a new stream channel and floodplain.
- Constructed 5 meander bends with natural pool-riffle sequences, increasing the channel length by 20%, increasing sinuosity, and decreasing average slope.
- Shaped about 40 acres of new floodplains.
- Constructed 1 mile of new side channels, side channel ponds, and other off-channel habitat.
- Spread about 5,000 cubic yards of soil and woody debris on the floodplains.
- Placed hundreds of trees into 10 engineered logjams along the channel.
- Monitored channel morphology, photo points, vegetation, and aquatic species.

Tasks completed in 2006: In 2006, construction work on the restored channel and floodplains was completed, and revegetation work was conducted on the areas that were restored in 2005. The second season of construction work was conducted between mid-May and early July 2006. The following tasks were accomplished in 2006:

- Constructed 1.2 miles of additional side channels and connected ponds.
- Reconstructed the lower 0.2 miles of Palmer Creek.
- Redistributed about 40,000 cubic yards of tailings piles to shape the channels and floodplains.
- Placed hundreds of trees into engineered logjams.
- Spread 3,000 cubic yards of soil and woody debris on the floodplains.
- Through a partnership with the Youth Restoration Corps (YRC), planted over 4000 birch seedlings, 600 spruce seedlings, and 4000 willow cuttings along the banks and on the floodplains.
- Monitored channel morphology, photo points, vegetation, and aquatic species.

Tasks completed in 2007: In 2007, revegetation was conducted on the areas that were restored in 2006 through a partnership with the Youth Restoration Corps. Work was conducted in June 2007. The following tasks were accomplished in 2007:

- Planted about 1000 spruce seedlings, 1800 birch, and 500 to 1000 sod transplants on the newly created floodplains.
- Planted about 4000 willow stems and 150 feet of sod and willow wraps along the banks of newly created side channels.
- Monitored channel morphology, photo points, vegetation, and aquatic species.

Tasks completed in 20008: In 2008, additional revegetation was conducted where needed through a partnership with Youth Restoration Corps. Work was conducted in June 2008. The following tasks were accomplished in 2008:

- Planted about 500 spruce seedlings, 900 birch, and 1000 willow stakes.
- Added numerous brush bundles to side channel ponds to increase nutrients and cover in these important rearing areas.
- Monitored channel morphology, photo points, vegetation, and aquatic species.

1.4 Document Organization

This document synthesizes and summarizes the channel morphology and vegetation monitoring conducted in 2005, 2006, 2007, and 2008, providing a comprehensive view of the short-term changes that have occurred in the 1 to 3 years since completion of various aspects of the project. The following monitoring questions are addressed in this document:

- ***Have the project objectives been met?*** The success of meeting each project objective will be examined quantitatively and qualitatively using a variety of data and information collected since project completion. This is addressed in Chapter 2 of this document. The objectives stated in Chapter 2 are from the pre-restoration channel analysis (Bair et al, 2002).

- ***What is the short-term response of the project area to restoration in terms of stream channel morphology and riparian vegetation growth?*** A variety of data and information will be used to evaluate various aspects of the restoration. This information will be used to improve future restoration designs and relate channel morphology features to aquatic habitat. Established survey sites will be available for measuring long-term changes and long-term response to restoration.

This report is the culmination of 3 years of monitoring on the Resurrection Creek Stream and Riparian Restoration Project. This report compiles and summarizes information from previous monitoring reports (MacFarlane, 2006; MacFarlane, 2007) and incorporates new data collected in 2008. Monitoring in 2008 occurred throughout the summer and fall of 2008. Channel morphology data and photo points were collected by Bill MacFarlane, Chugach National Forest Hydrologist. Vegetation growth and survival data were collected by Dean Davidson, retired Chugach National Forest Soil Scientist. Vegetation composition data were collected by Rob DeVelice, Chugach National Forest Ecologist. Fish population data monitored since project completion are presented in a separate report.

2 ACHIEVEMENT OF RESTORATION OBJECTIVES

2.1 Floodplains

Objective: Increase the amount of available floodplain for the main channel and side channels by increasing the entrenchment ratio (the ratio of the floodprone width to the bankfull width) from about 1:1 to greater than 6:1 (Bair et al., 2002).

Need for objective

Historic placer mining on Resurrection Creek created numerous tailings piles up to 30 feet high along both sides of the Resurrection Creek channel. The channel was moved and straightened during historic mining, and the tailings piles along both banks covered important floodplain area. Flood flows in Resurrection Creek had no ability to spread out onto a floodplain, resulting in confined, high velocity flows, poor fish habitat, poor retention of large woody debris, few pools, little habitat diversity, and poor riparian health. Without floodplains, Resurrection Creek could not deliver nutrients to the riparian area, and the tailings piles prevented the development of side channels that would have provided important rearing habitat and flood relief. Reference conditions suggested that floodplains were about 6 times as wide as the bankfull channel width, and it is assumed that these conditions existed in the project reach prior to historic placer mining.

Accomplishments

During the 2005-2006 restoration project, a total of about 160,000 cubic yards of tailings piles were redistributed throughout the reach to create new floodplain along the newly created channel. Where new meanders were constructed, portions of the old channel were filled in to create floodplains. Side channels were constructed in these new floodplain areas.

Evaluation methods

The entrenchment ratio of the newly constructed Resurrection Creek channel was quantified by surveying cross sections in typical main channel riffles and surveying valley-wide cross sections. Cross section surveys were conducted using standard stream survey methods (Harrelson et al., 1994; Rosgen, 2006). Valley widths and floodplain widths were also analyzed on a reach scale using LIDAR elevation data. For the purpose of this evaluation, the floodprone elevation is defined by a water surface elevation that is twice the maximum bankfull depth in a riffle cross section. Everything below the floodprone elevation is considered to be floodplain at a particular cross section.

Results

The project area lies within a 4700-foot long valley, and the extent of the valley floor is about 45.7 acres, defined by the edges of the high terraces and valley slopes. The with of the valley floor through most of the project reach ranges from about 300 feet to 700 feet wide, averaging about 420 feet. This is the width that was available for floodplain creation during this project (**figure 2.1**).

Prior to restoration, the floodprone width was only slightly wider than the channel width because of the constriction caused by tailings piles. As a result of restoration, about 70% of the valley floor now consists of stream channels and floodplains, for a floodprone area of 31.8 acres over a linear valley distance of 4700 feet. The main channel of Resurrection Creek, Palmer Creek, and Channel 1 cover 12.3 acres, and floodplains cover 19.5 acres. The floodprone width ranges from 200 to 500 feet, averaging about 290 feet in width over the length of the project reach. Based on these generalizations and an average bankfull channel width of about 75 feet, the entrenchment ratio ranges from about 3 to 7 and averages about 4.

Field measurements verify these map-based generalizations. Entrenchment ratios measured at 3 sites in the field ranged from 3.4 to 5.3 (**table 2.1**, **figure 2.2**).

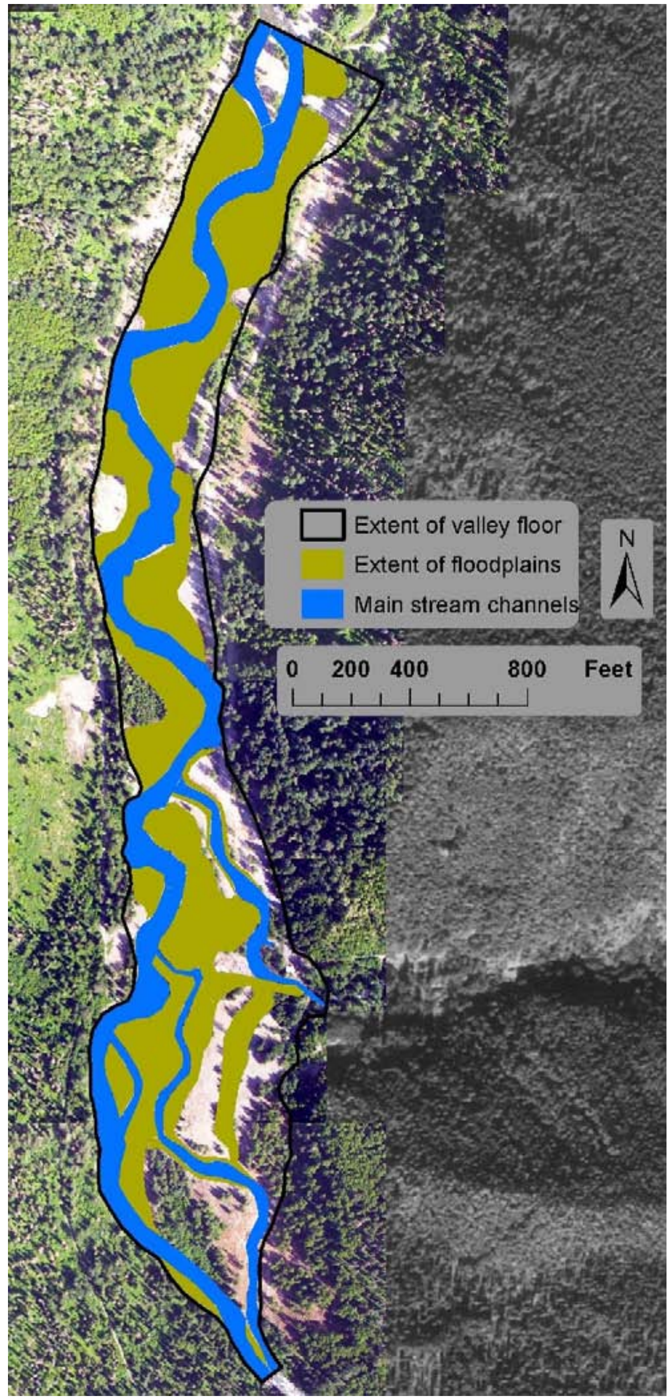
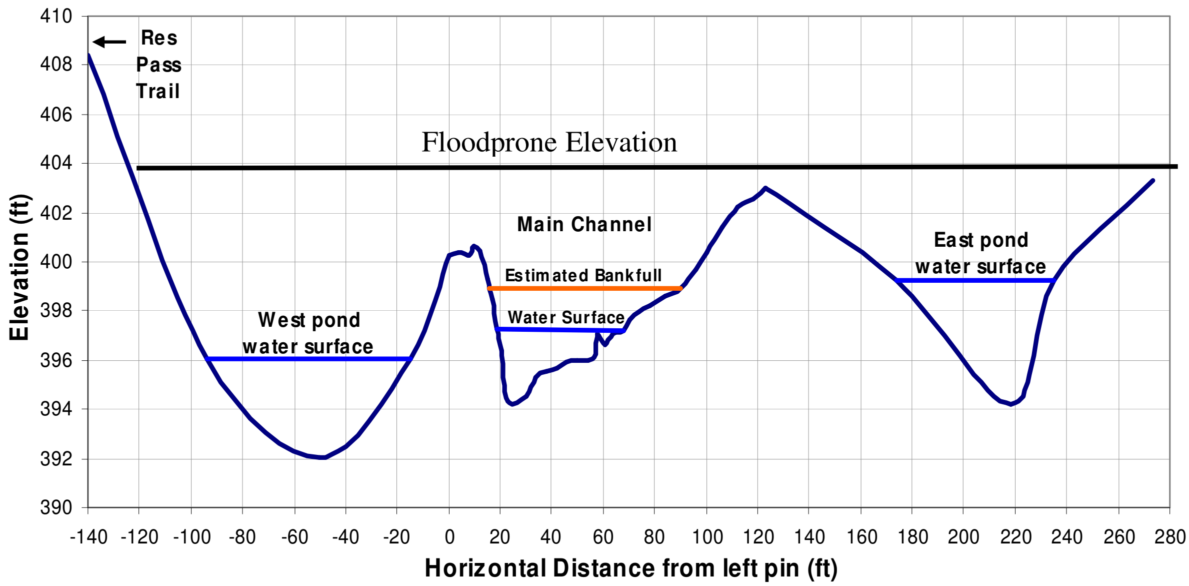


Figure 2.1: Extent of valley floor and locations of floodplains and main stream channels in the Resurrection Creek project area following restoration.

Table 2.1: Entrenchment ratios for measured sites in the Resurrection Creek project area.

Site	Floodprone width	Bankfull channel width	Entrenchment Ratio
Valley cross section at riffle cross section 8+90	390 feet (measured)	74 feet	5.3
Riffle cross section 14+82	320 feet (estimated)	75 feet	4.7
Upper Valley cross section	550 feet (estimated)	160 ft (combined main channel and Channel 1)	3.4



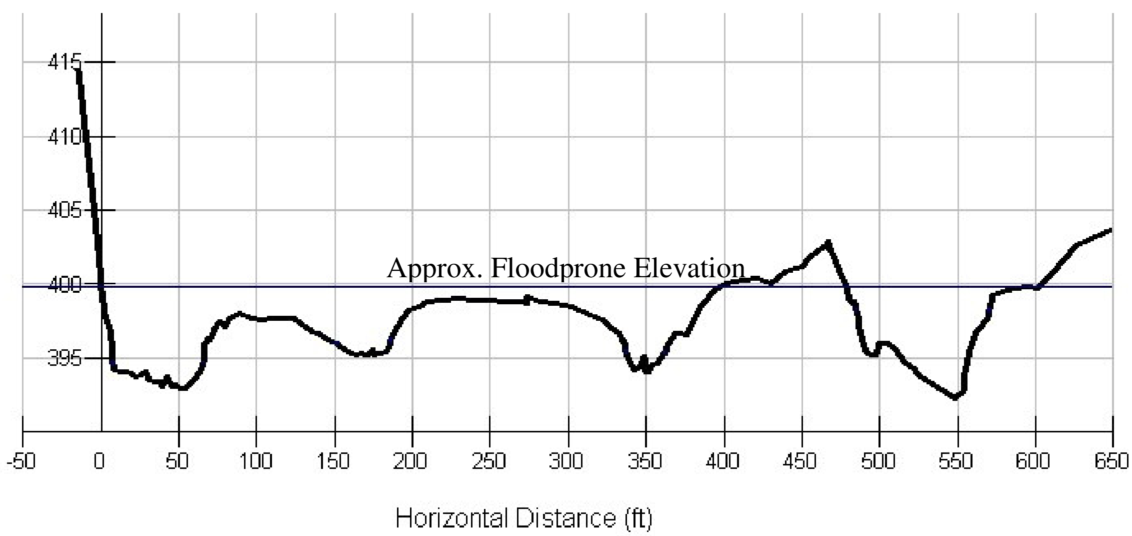


Figure 2.2: Valley cross sections at riffle cross section 8+90 (top) and upper valley cross section (bottom), showing floodprone elevations and widths (10X vertical exaggeration).

Entrenchment ratios in the restored reach average about 4. This is less than the stated objective (entrenchment ratios greater than 6). However, the floodprone width was limited in places by narrower valley widths, as little as 300 feet, which would only allow for entrenchment ratios of up to about 4. In other areas, constructing floodplains greater than 450 feet was impractical or would have been cost prohibitive. Entrenchment ratios of about 4 will likely be sufficient to allow for floodplain function for this channel.

Many of the floodplains constructed as part of this project slope gently toward the channel, and in general, many of these floodplains are not flat. This tends to keep flood flows funneled into the main channel, helping to ensure that the channel remains stable. However, because the floodplains are not flat like the more naturally formed floodplains in the reference reach, floodplain widths, over-bank flows, and side channel development may be somewhat limited as compared to reference conditions.

Most of the side channels within the project area lie within the floodplain of the main Resurrection Creek channel. However, portions of Channel 1 and Palmer Creek have their own floodplains, with higher ground separating these channels from the main channel. The upper half of Channel 1 and the lower portion of Palmer Creek have relatively narrow floodplains. The upper half of Channel 1 has entrenchment ratios of less than 2, and lower Palmer Creek has entrenchment ratios of about 1.4 to 2.5 (MacFarlane, 2007).

2.2 Channel pattern

Objective: Reconstruct the main channel of Resurrection Creek from a straight channel to a meandering channel by increasing the channel length by about 15% and increasing the sinuosity from 1.1 to 1.4 (Bair et al., 2002).

Need for objective

As a result of historic placer mining, Resurrection Creek was straightened. The resulting stream channel was simplified in terms of function and habitat. Confined by tailings piles on both banks, this straightened channel resulted in an increased channel slope, higher stream velocities, impaired aquatic habitat, increased substrate size, and lack of pools. The channel design for restoration was based on the “Floodplain” process group (USDA Forest Service, Alaska Region, 1992) or “C” channel (Rosgen, 1994) in the reference reach, which has a sinuosity of about 1.4. Creating sinuosity in the restored reach would be the basis for decreased channel slope, development of pool-riffle sequences, increased channel complexity, and improved aquatic habitat.

Accomplishments

During channel restoration, five meander bends were constructed. These channel segments were constructed “in the dry” one at a time, prior to diversion of the water into the new segment. These five meander bends are the basis for the restored channel pattern, but additional small adjustments to the thalweg and channel pattern were made throughout the reach by sculpting floodplains, constructing side pools, placing boulders, and connecting side channels.

Evaluation methods

Channel pattern variables, including channel length, valley length, sinuosity, meander wavelength, radius of curvature, and belt width were analyzed primarily using LIDAR elevation data and ortho-rectified aerial photography. Methodologies for measuring some of these variables are defined in Rosgen (2006).

Results

As a result of the construction of the five meander bends and additional small adjustments to the stream channel, the channel thalweg length was increased by about 920 feet over the length of the entire 1-mile long reach (**table 2.2**, **figure 2.3**). This corresponds to an 18% increase in channel length, for a restored length of 6140 feet. Most of the increase in channel length and all five of the constructed meander bends were in the lower 4300 feet of the restored reach. Little change occurred in the channel pattern of the upper 1700 feet of the restored reach, where some sinuosity previously existed.

Increases in sinuosity are directly related to the increases in channel length. Over the length of the entire reach, sinuosity increased from 1.07 to 1.26, or an increase of about 18%. Most of the increased sinuosity is the result of the five constructed meanders in the lower 4300 feet of the restored reach, whereas the upper 1700 feet of the reach experienced little change in sinuosity.

Table 2.2: Channel lengths and sinuosities before and after restoration for the entire reach, the upper reach, and the lower reach, as shown in **figure 2.3**.

		Valley length	**Thalweg length**	**Sinuosity**	**Percent Increase**
Entire Reach	Pre-restoration	4870	5218 ft	1.07	18%
	Post-restoration		6140 ft	1.26	
Upper Reach	Pre-restoration	1700	1865 ft	1.10	1%
	Post-restoration		1892 ft	1.11	
Lower Reach	Pre-restoration	3170	3353 ft	1.06	27%
	Post-restoration		4248 ft	1.34	

Variables describing the channel geometry of the lower portion of the project reach were analyzed in the *Resurrection Creek Restoration 2005 Channel Morphology Monitoring Report* (MacFarlane, 2006). These data indicate that based on ratios of meander wavelength to bankfull width (*Lm*/*Wbkf*) and radius of curvature to bankfull width (*Rc*/*Wbkf*), the restored channel has attained relatively stable characteristics for a this type of channel.

Sinuosity is an important characteristic of low gradient, unconfined channels with floodplains, or 'C' channels as defined by Rosgen (1994). Increasing channel length and restoring sinuosity to previously channelized floodplain channels has numerous benefits to both the stream channel function and aquatic habitat. Increased channel length provides a larger amount of available spawning and rearing habitat for salmon. Sinuosity allows for natural processes of scour to occur in the pools on each bend. Without sinuosity, constructed pools would tend to fill with sediment, but the helical flow created at these bends and the localized scour created by the logjams at high flow work together to keep deep pools and deposit fresh gravel on the point bars and in the pool-tail or glide areas. These glides are valuable areas for spawning. Development of pool-riffle sequences provides habitat diversity, with different areas for spawning, rearing, and macroinvertebrate production that did not exist prior to restoration.

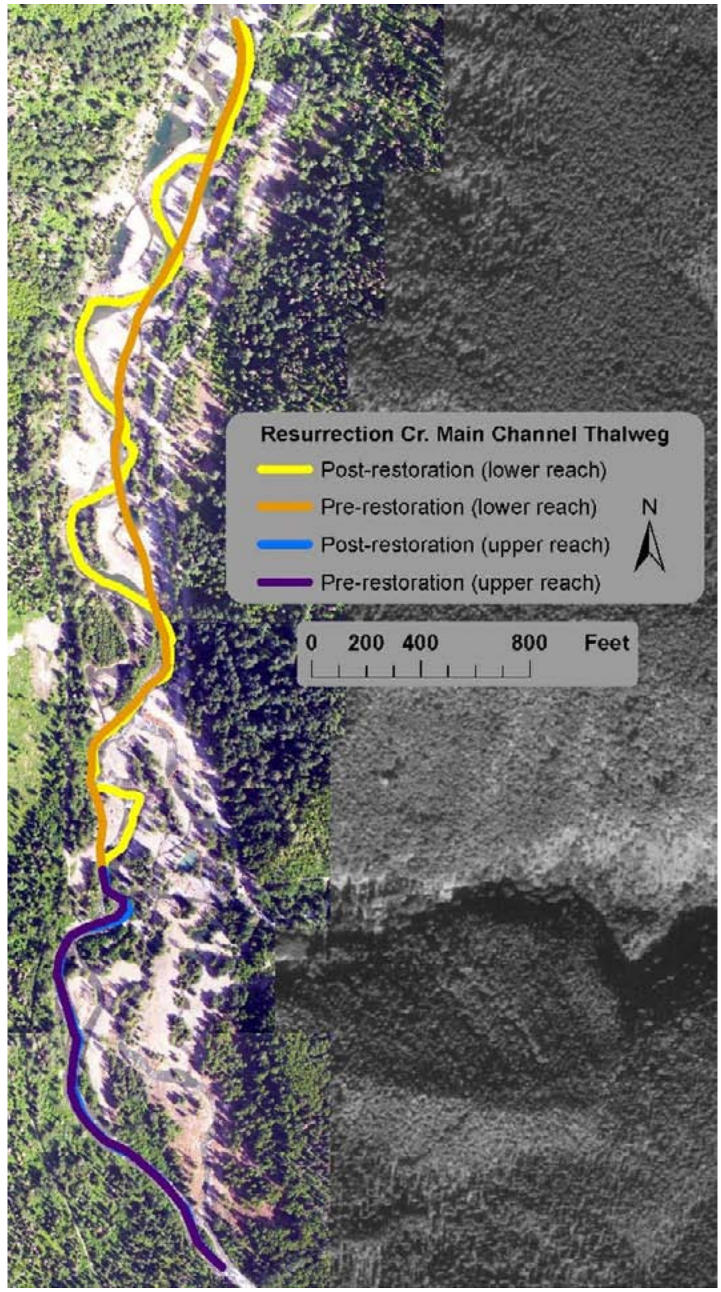


Figure 2.3: Comparison of the pre-restoration main channel and the post-restoration main channel.

Most of the side channels were constructed with moderate sinuosity, similar to the main channel, in order to provide the same benefits as in the main channel. The sinuosity of Channel 1 and Palmer Creek are both about 1.2.

2.3 Channel profile

Objective: Decrease the average main channel slope from about 1.5% to 1.1%. Construct pool-riffle sequences in the main channel by constructing pools on the outsides of the bends, increasing the number of pools per river mile from about 3 to 23 (Bair et al., 2002).

Need for objective

As a result of historic placer mining, Resurrection Creek was straightened and steepened over pre-existing conditions. This resulted in higher flow velocities, higher shear stresses, larger substrate, fewer pools, decreased large woody debris retention, and degraded aquatic habitat. Prior to restoration, riffles comprised almost the entire reach, with very few pools, creating a homogenous, high energy environment. Decreasing the channel slope through channel restoration creates lower energy environments more suitable for spawning and rearing, and allows for the construction of stable pool-riffle sequences. Pool-riffle sequences provide diverse habitat types throughout the reach and a stable configuration for this type of stream in this valley type.

Accomplishments

Increasing the channel length by constructing 5 meander bends corresponded to a decrease in average channel water surface slope. Pools were constructed on the outside of each meander bend, and riffles were constructed in the straight cross-over sections between each bend. Pools and riffles were designed to emulate natural conditions measured in the reference reach in terms of widths, depths, slopes, and substrate.

Evaluation methods

Channel slopes were measured in the field for the lower 4300 feet of the reach by measuring a longitudinal profile in 2005 (MacFarlane, 2006), using standard stream surveying methods (Harrelson et al., 1994; Rosgen, 2006). This profile also shows the locations and depths of each pool, as well as the water surface slopes of the individual pools and riffles. Longitudinal profiles were also measured for Channel 1 and Palmer Creek in 2006 (MacFarlane, 2007). LIDAR data analyzed using GIS provide a more generalized view of the water surface slope though the entire reach.

Results

By increasing the main channel length by about 920 feet, the average water surface slope of the main channel was decreased from 1.53% to 1.30% (**table 2.3**). The majority of the change in slope occurred in the lower 4300 feet of the reach, where the five meander bends were constructed. This lower portion of the reach was also the steepest portion of the reach prior to restoration, with a pre-restoration slope of 1.64%. Little change occurred in the main channel in the upper 1900 feet of the reach, which had a slope of 1.34% prior to restoration.

Table 2.3: Channel slope of the main channel before and after restoration for the entire reach, the upper reach, and the lower reach.

		Thalweg length	Elevation difference	Average slope	Percent Difference
Entire Reach	Pre-restoration	5218 ft	80 ft	1.53%	15%
	Post-restoration	6140 ft	80 ft	1.30%	
Upper Reach	Pre-restoration	1865 ft	25 ft	1.34%	2%
	Post-restoration	1892 ft	25 ft	1.32%	
Lower Reach	Pre-restoration	3353 ft	55 ft	1.64%	21%
	Post-restoration	4248 ft	55 ft	1.29%	

Pool-riffle sequences were created during the restoration project, with substantial pools located on the outside of most meander bends. Within the lower 4300 feet of the restored reach, riffle slopes ranged from 1.4% to 3.9%, averaging 2.9% (**figure 2.4**). Riffle slopes averaged about 2 times the average water surface slope. Pool water surface slopes approached 0.0%. The pool-riffle morphology that was constructed and the differences in water surface slope among these different bedforms result in a variety of different processes, substrate compositions, and habitat types in different portions of the reach.

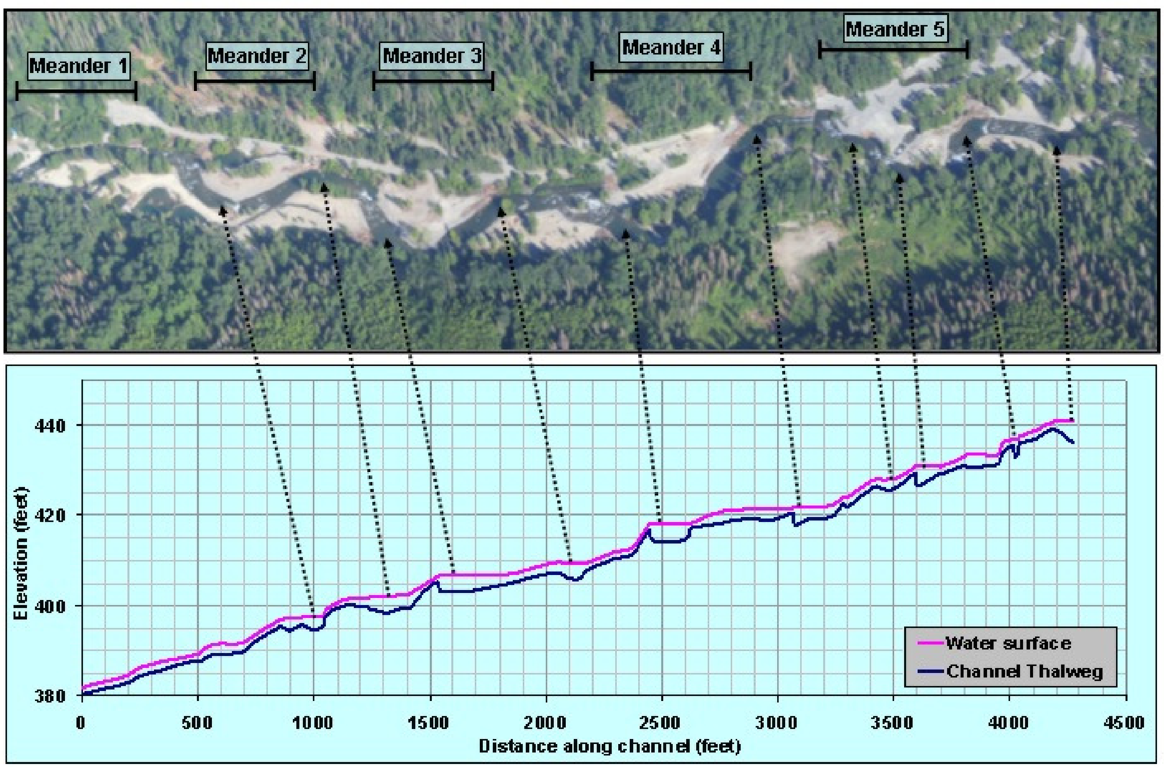


Figure 2.4: Longitudinal profile of the lower 4300 feet of the restored channel, showing the locations of the 10 pools constructed in the main channel.

Pools are naturally located at the outsides of meander bends, and the restored reach was constructed to emulate this natural configuration. The meander wavelength, which is defined by 2 meander bends and generally consists of 2 pools, ranges from 464 feet to 817 feet and averages 683 feet (MacFarlane, 2006). Based on the designed meander wavelength, the restored channel would have no more than about 15.5 pools per mile.

Analysis of the 2005 longitudinal profile of the lower 4300 feet of the main channel shows that 10 pools exist within this 4300-foot reach. The pool-to-pool spacing ranges from 175 to 540 feet and averages 372 feet. This corresponds to an average pool-to-pool spacing of 5.2 bankfull channel widths, which is typical for a "C" channel such as this. Based on this longitudinal profile, this reach has about 12 pools per mile. These 10 pools exist within a 3500-foot reach, as the lower 800 feet of the project reach is a transition area with no pools. About 15 pools per mile exist over this 3500-foot reach.

Over the lower 4300-foot reach of the project reach, pools now comprise about 21% of the length of the reach, whereas prior to restoration, pools comprised about 1% of the length of the reach (MacFarlane, 2006). This represents a considerable increase in the amount of slow-water rearing habitat available in Resurrection Creek.

2.4 Side channels

Objective: Construct varied side channel habitat throughout the reach and increase the percentage of the total Resurrection flows that is in these side channel flow from <1% to 5-20% (Bair et al., 2002).

Need for objective

Prior to the 2005-2006 restoration project, less than 1% of the total flow of Resurrection Creek in the project reach was in side channels, and off-channel habitat was very limited. This was identified as the limiting factor for coho salmon production in this reach (Hart Crowser, 2002), as it has been shown that off-channel pond habitat can provide beneficial rearing and over-wintering habitat in these systems. A restoration project conducted in the 1990s in this same reach of Resurrection Creek created three small side channels that connected small ponds amongst the tailings piles. While these likely provided beneficial aquatic habitat, they were limited in size, extent, and volume of flow, and were not associated with floodplains. Side channels within functional floodplains provide flow refugia during high flows, increase the amount of available habitat, and help reduce shear stresses in the main channel during floods, functioning as integral parts of the floodplain. These side channels also create wetlands and improve riparian growth.

Accomplishments

The construction of side channels was an integral part of the 2005-2006 restoration project. Side channels were constructed as a part of nearly every meander bend. Where new meander bends were created, some areas of the old main channel were left unfilled to create ponds, which were then connected to the main channel through side channels. Most of the side channels initiate at pools, where constructed logjams regulate the amount of flow going into the side channel. The side channel inlets were constructed deep enough to capture perennial flow, while the logjams prevent excessive flows from going into the side channel during high flows.

Evaluation methods

An inventory of all side channels in the project area was conducted. Flows were estimated in these side channels at two different flow levels during the summer of 2008 to give an estimation of the percentages of the total flow in side channels at various places within the project reach. Flows were estimated by multiplying the measured cross sectional area (width times average depth) by the estimated average flow velocity. These estimates are not highly accurate, but give a good representation of the distribution of flow volume in the various channels.

Results

A total of 15 side channels were constructed as a part of this restoration project (**table 2.4**, **figure 2.5**). These side channels range in length from 165 feet to 1825 feet long, with bankfull channel widths of 9 feet to 50 feet. The total of 9420 feet of side channels were constructed. These side channels comprise a variety of habitat types and function, including large split channels from the main channel, flood relief channels, wetland and pond connector channels, and groundwater-fed sloughs. Many of these side channels incorporate ponds, which provide rearing and overwintering habitat for salmon fry. A total of 2.1 acres of ponds were created as part of these side channel networks.

The percentage of the total flow in Resurrection Creek in side channels varies at different points within the reach. Numerous interconnected side channels exist in the upper portion of the reach, upstream of the Palmer Creek confluence. Channel 1 typically carries about 10 to 15% of the total flow of Resurrection Creek upstream of the Palmer Creek confluence. The Upper Split Channel typically carries about 15 to 20% of the total flow. A few additional side channels carry less than 5% of the flow. The amount of flow in side channels at most points upstream of the Palmer Creek confluence varies from about 5% to 34% at normal summer flows and high flows. The percentage of side channel flow decreases as flows decrease in Resurrection Creek.

Palmer Creek is not technically a side channel, although Channel 2 and one of the Palmer Creek connector channels route water into Palmer Creek, and the lower 850 feet of Palmer Creek was reconstructed within the floodplain to act as a flood relief channel for Resurrection Creek.

Smaller side channels exist in the lower portion of the project reach. Most of the side channels in the lower reach carry less than about 5% of the total flow of Resurrection Creek downstream of the Palmer Creek confluence, with the exception of the Meander 1 Split Channel, which carries about 35 to 40% of the total flow. At most points in the lower portion of the reach, side channels carry between 1 and 5% of the total flow of Resurrection Creek at normal summer flows and high flows. The percentage of side channel flow decreases as flows decrease in Resurrection Creek.

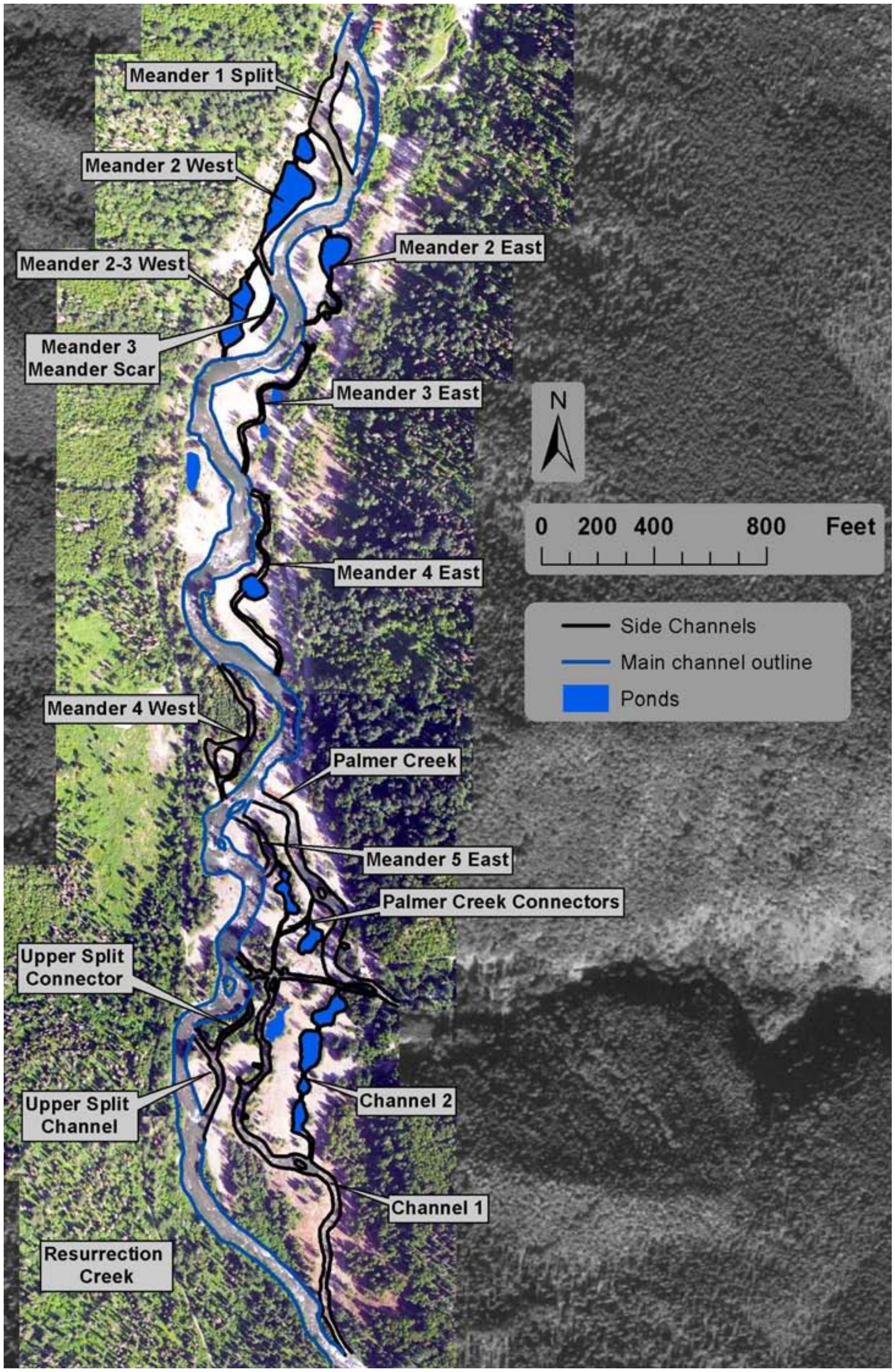


Figure 2.5: Locations of side channels in the Resurrection Creek project area.

Table 2.4: Side channel characteristics for the Resurrection Creek project area. Side channel locations are shown in **figure 2.5**.

Side channel	**Side Channel Length**	**Avg. bankfull channel width**	**Pond Area**	**Estimated flow at typical low-moderate flow (9-29-08)**		**Estimated flow at typical moderate-high flow (7-8-08)**	
Upstream of Palmer Creek Confluence							
Total flow in Resurrection Creek				**250 cfs**		**550 cfs**	
Channel 1	1825 ft	36 ft	0.11 ac	35 cfs	14%	80 cfs	15%
Channel 2	880 ft	15 ft	0.50 ac	1 cfs *	0.4%	6 cfs	1%
Upper Split Channel	370 ft	35 ft	0 ac	40 cfs	16%	100 cfs	18%
Upper Split Connector	245 ft	18 ft	0 ac	20 cfs	8%	25 cfs	5%
Palmer Cr Connectors (2)	660 ft	9 ft	0.12 ac	0.5 cfs	0.2%	2 cfs	0.4%
Meander 5 East	270 ft	30 ft	0 ac	15 cfs	6%	25 cfs	5%
Downtream of Palmer Creek Confluence							
Total flow in Resurrection Creek				**300 cfs**		**700 cfs**	
Palmer Creek (tributary)	850 ft	43 ft	0 ac	50 cfs	17%	150 cfs	21%
Meander 4 West	800 ft	30 ft	0 ac	3 cfs	1%	16 cfs	2%
Meander 4 East	830 ft	17 ft	0.13 ac	2 cfs*	0.7%	10 cfs *	1%
Meander 3 East	675 ft	15 ft	0.08 ac	4 cfs*	1.3%	15 cfs	2%
Meander 2-3 West	375 ft	13 ft	0.29 ac	2 cfs*	0.7%	18 cfs	3%
Meander 2-3 meander scar	165 ft	10 ft	0 ac	2 cfs	0.7%	2 cfs	0.3%
Meander 2 East	450 ft	11 ft	0.23 ac	2 cfs	0.7%	14 cfs *	2%
Meander 2 West	625 ft	20 ft	0.59 ac	1.5 cfs*	0.5%	20 cfs *	3%
Meander 1 West Split	400 ft	50 ft	0 ac	120 cfs	40%	250 cfs	36%

** Estimated flows reported as side channel inflow. A portion of the inflow infiltrates into the substrate.*

Not all side channels carry perennial flows during low flow conditions in the winter. This is the result of insufficient depth in the channel inlets constructed beneath some of the logjams. Groundwater seepage contributes additional flow to many of these channels.

Some of the side channels lose flow as water percolates into the porous gravels and ultimately back into Resurrection Creek. This effect is pronounced at the Meander 2 West, Meander 2 East, and Meander 4 East side channels. During low flows, water flows into the side channel ponds, but no surface water flows out of the pond.

2.5 Aquatic habitat

Objective: Increase the amount of available spawning gravel from 160 to about 2000 yd^2 per river mile, and increase the amount of large in-stream wood from 8 to 330 pieces per river mile (Bair et al., 2002).

Need for objective

A major limiting factor in this reach prior to restoration was the lack of available spawning and rearing habitat for anadromous and resident fish. The development of abundant and varied habitat was one of the main reasons for conducting this restoration project. Prior to restoration, in-channel woody debris was very scarce because of the typically high velocities moving through the straight, steep, riffle-dominated channel, with only about 8 pieces of woody debris per river mile. Natural recruitment of woody debris was limited because of the poor condition of the riparian vegetation on the banks. Also, most of the woody debris that entered the reach from upstream was flushed through the reach, with few places in which to hang up or develop logjams.

The pre-restoration reach was also riffle-dominated. With few pools and a generally high energy environment, the substrate was larger than would be expected with a natural meandering pool-riffle channel. With very few pools, natural sorting and accumulation of spawning gravel was very limited, with only about 160 square yards of spawning gravel per river mile. In addition to these characteristics, the pre-restoration reach lacked pool habitat, off-channel rearing habitat, and overhanging bank habitat. The lack of off-channel rearing habitat was considered a limiting factor for coho salmon production (Hart Crowser, 2002).

Accomplishments

Abundant habitat was created during this project in conjunction with the other restoration tasks and accomplishments. By constructing a natural meandering channel with pool-riffle sequences, numerous pools were created, providing abundant rearing habitat. Log jams incorporated into the pool design provided cover for fish in these low-energy areas. The log jams were constructed where woody debris would normally accumulate, on the outsides of bends in pool sections. Most of the woody debris placed in the channel is within these logjams. Wood within these logjams was keyed into the ground, providing a strong matrix of interlocking log elements. Additional woody debris was placed on the upstream ends of islands, along some of the banks, and across some of the smaller side channels.

Deep pools were created on the outside of each bend in the main channel. Natural sediment dynamics cause smaller gravel to accumulate in the pool tail, or glide area at the downstream end of each pool, where flow energy is lower and the channel gradient transitions from pool to riffle. Rather than sort and place appropriately sized spawning gravel in these areas, gravel was allowed to naturally accumulate as the channel adjusted itself following restoration. Additional spawning and rearing habitat was created within the side channels, using similar techniques as were used in the main channel.

Evaluation methods

Woody debris was counted, and the extent of spawning habitat was quantified in July 2008 throughout the entire project reach, including the side channels. Woody debris counts were made for two size classes - greater than 12 inches in diameter and less than 12 inches in diameter. Using the Region 10 stream habitat survey methodology (USDA Forest Service, Alaska Region, 2001), a complete habitat survey was also conducted in 2007 through the restored reach (Martin, 2007), providing information on woody debris, pool habitat area, off-channel habitat area, and fish populations.

Results

Woody Debris

A total of about 27 log jams were constructed within the project reach. Half of these are major log jams constructed on the main channel, and the others are smaller log jams constructed on Channel 1 and the lower reach of Palmer Creek (**table 2.5, figure 2.6**). While the main channel log jams each contain between about 10 and 50 logs, the smaller logjams contain 5 to 20 logs each. These logs are a mixture of sizes and lengths. Most of the logs are spruce, and some are cottonwoods. These logjams are partially within the bankfull channel and partially on the floodplain. Additional in-channel woody debris is found scattered throughout the reach, on the main channel and side channels.

Table 2.5: Logjams in the Resurrection Creek project area.

Channel	Number	Notes
Main Channel	14 log jams	Major logjams, 10 to 50 logs in each, act as side channel inlet structures
Channel 1	9 log jams	Minor logjams, 5 to 20 logs in each, on outsides of bends
Palmer Creek	4 log jams	Minor logjams, 5 to 20 logs in each, on outsides of bends, one cross-channel

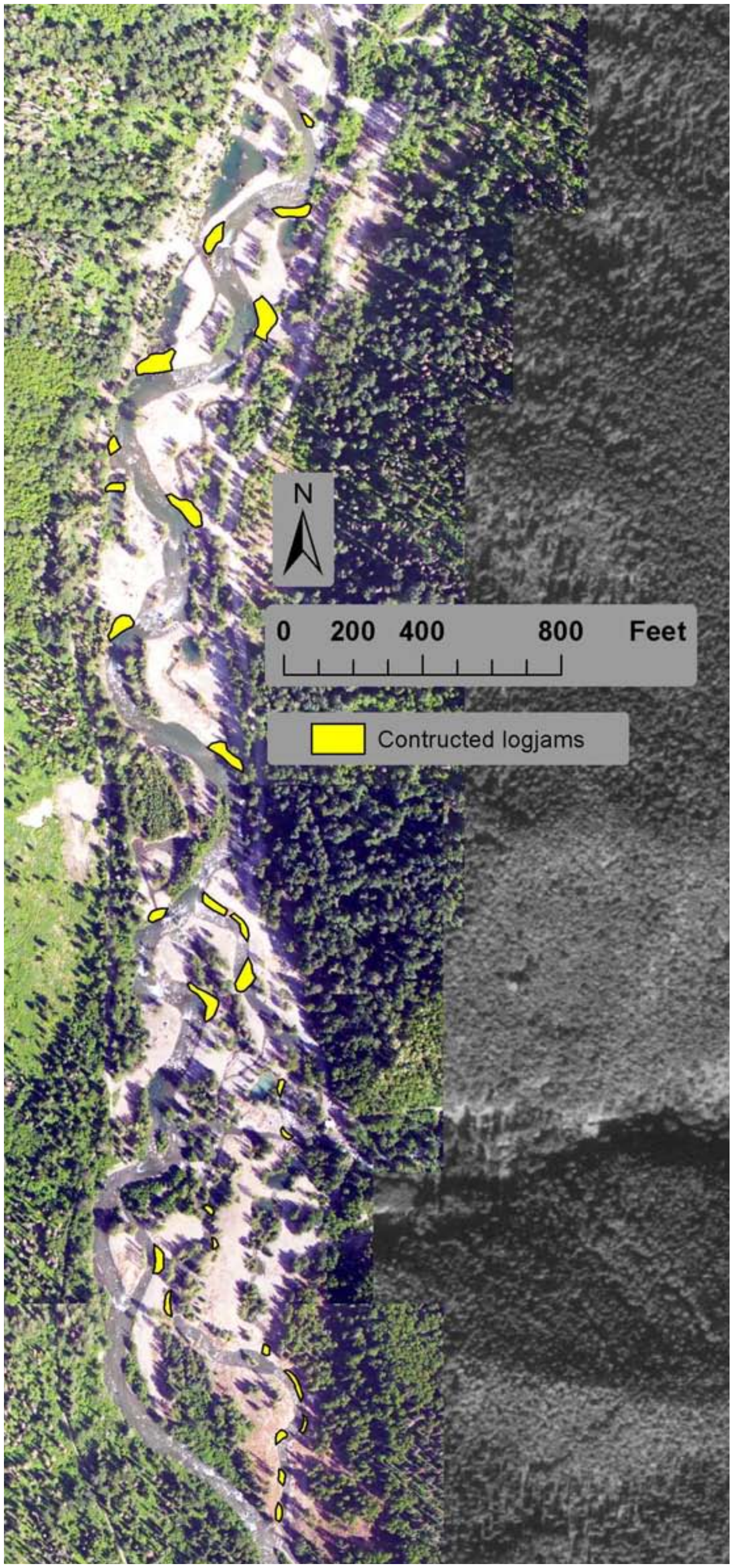


Figure 2.6: Locations of logjams within the Resurrection Creek project area.

Results of a 2008 in-channel woody debris count over the entire project area, including the main channel and side channels, show a total of 588 pieces of woody debris within the bankfull channel. The majority of the woody debris counted (427 pieces) was less than 12 inches in diameter, and 161 pieces were greater than 12 inches in diameter (**table 2.6**). Using different woody debris size classes, Martin (2007) measured a similar amount of large woody debris in the main channel and side channels. Martin (2007) observed more than 3 times the amount of in-channel woody debris in 2007 as compared to pre-project conditions in 2004.

The project area consists of 1.2 miles of main channel. Major side channels include Channel 1 (0.15 miles) and Palmer Creek (0.35 miles). The amount of woody debris per stream mile was calculated using the total mileage of only the main channel and 2 major side channels, for a total channel length of 1.7 miles. A total of 251 pieces of woody debris less than 12 inches in diameter were counted per stream mile, and a total of 95 pieces of woody debris greater than 12 inches in diameter were counted per stream mile.

Table 2.6: Results of 2008 in-Channel Woody debris count.

Category	**Number**	**Number per mile**
<12 inches diameter:	427 pieces	251 pieces/river mile
>12 inches diameter:	161 pieces	95 pieces/river mile
All LWD counted:	588 pieces	346 pieces/river mile

The amount of in-stream wood per stream mile was similar to the objective of 330 pieces per stream mile. The original objective was to increase woody debris in these larger size classes. However, much of the woody debris used to construct logjams and other in-channel features was less than 12 inches in diameter. This is the result of the smaller size of trees growing on this part of the Kenai Peninsula. However, while spruce does not always achieve large diameters, many of the cottonwoods used in the channel are considerably larger than 12 inches in diameter.

The constructed logjams have held up well in the 2 to 3 years since their construction. They were designed to maintain themselves through continued recruitment of new wood from upstream. Woody debris has been observed floating from upstream of the restored reach, often the result of beetle-kill spruce that has fallen into the channel during high flows. In some cases, these logs have accumulated on existing logjams or at the heads of islands within the project reach (**figure 2.7**).

Beavers are another important factor affecting wood accumulation in the project reach. Beavers have felled numerous trees along the Resurrection Pass Trail near where it is adjacent to Meander 3. Many of these trees have fallen into the pool at Meander 3 and have lodged into the log jam, providing extra habitat and adding to the integrity of the logjam (**figure 2.7**). The only observed beaver dam in the project area is located in the upper project area, enlarging a small pond adjacent to the lower end of Channel 1. No side channels have been blocked by beaver dams up to this point.

Figure 2.7: Accumulation of new trees felled by beavers into the Meander 3 logjam, and accumulation of trees at the head of and island at the Meander 4 riffle.

Spawning Gravel

A 2008 survey of extent of spawning gravel throughout the entire project reach, including the main channel and major side channels, indicated a total of about 2,300 square yards of spawning gravel. Over a stream channel distance of 1.7 miles (including the main channel, Channel 1, and lower Palmer Creek), this is about 1350 square yards per stream mile. This is a considerable improvement in quantity of habitat from prior to restoration (160 square yards per stream mile), but not quite as high as the project objective of creating 2,000 square yards per stream mile. Fewer pools and less spawning gravel exist in the upper 1500 feet of the main channel, while spawning habitat is more abundant in the lower portion of the project area and the lower portion of Palmer Creek.

Over the course of 2 to 3 years, spawning gravel has been observed accumulating in the pool tail, or glide areas at the downstream ends of the large main channel pools. The spawning gravel that naturally accumulates in these areas consists of abundant gravel in the 45mm to 64mm range, with larger material scattered throughout, and smaller material being deposited on new point bars. This gravel is generally well sorted. The pool tail at Meander 3 is a typical glide with abundant spawning gravel (**figure 2.8**). A point bar is also seen developing on the inside of the bend at this location.

Excellent spawning gravel also exists on Palmer Creek (**figure 2.9**) and in portions of Channel 1 (**figure 2.10**). Surveys of cross section 3+61 in Palmer Creek shows accumulation of abundant gravel in the 16mm to 32mm size class (averaging 21mm) in long sections of low gradient channel where spawning habitat exists. On Channel 1, spawning gravel observed in pool tails (XS 5+55) and low gradient sections (XS 1+05) are predominantly in the 22mm to 90mm size range, averaging about 34 to 49mm.

Figure 2.8: Spawning area on the main channel at the Meander 3 pool-tail (Aug 31, 2007).

Figure 2.9: Spawning area on a low gradient section of Palmer Creek (Aug 27, 2008).

Figure 2.10: Spawning area in pool tail on Channel 1 (Aug 27, 2008).

2.6 Riparian Vegetation

Objective: Restore topsoil to at least 80% of the floodplain and increase coarse woody debris on the floodplain from 16 to about 120 pieces per acre. Decrease overstocked riparian tree densities, restore tree composition (50% spruce, 40% cottonwood, and 10% birch and hemlock), and reestablish ground cover (Bair et al., 2002).

Need for objective

Prior to restoration, portions of the project area consisted of large tailings piles, some up to about 30 feet high. The surface of these tailings piles was predominantly cobbles, with little or no soil cover. Riparian vegetation was sparse in these areas. Soil and riparian vegetation were better in areas not occupied by tailings piles.

Channel and floodplain construction required the redistribution of tailings piles to create floodplains along the new channel. In the construction process, only about 25% of the area remained as it was prior to restoration, and about 75% of the total project area was altered through this tailings pile manipulation and channel construction. Restoring the topsoil to these new floodplain areas was needed to start the floodplain and riparian vegetation growth on the new floodplains.

Woody debris on the floodplain is an important component of the natural ecosystem. Floodplain woody debris provides wildlife habitat as well as nutrients and organic material for the soil and vegetation. Floodplain woody debris also creates floodplain roughness, which can help limit high velocity overbank flows and provide flow refugia for aquatic organisms.

The riparian forest is a vital portion of the aquatic ecosystem, providing wildlife habitat, floodplain roughness, and recruitment of in-channel woody debris. Prior to restoration, the riparian forest was limited by the poor growing conditions on the tailings piles. The ideal forest composition consists of a variety of species and age classes and well established ground cover.

Accomplishments

Following restoration, about 8,000 cubic yards of soil were spread onto the newly created floodplains. This soil was taken from forested areas to the east and west of the project area, and a limited amount of soil was imported from off-site. Because soil sources were more plentiful on the west side of the project area and transportation of soil across the main channel was not possible, the floodplains on the west side of Resurrection Creek were more fully covered. A mixture of clay, sand, gravel, and cobbles was spread over areas of the floodplain on the east side of Resurrection Creek where organic soil was not available. Soil was spread down to the approximate elevation of the bankfull flows.

Woody debris was spread onto the floodplain wherever possible. Some of the woody debris on the floodplain is part of the large logjam complexes constructed on the outsides of the main channel meander bends.

Wherever existing floodplain elevations did not need to be disturbed for the construction of the new channels and floodplains, riparian vegetation and trees were left intact, leaving islands of existing mature riparian forest throughout the project area. Many areas of "dog-hair" spruce were removed to reconstruct floodplain or channel. Newly constructed floodplains were re-vegetated through three seasons of planting, seeding, and natural regeneration. Spruce and birch were planted on the floodplains, and willow stakes were planted along the channels. Much of the ground cover was naturally regenerated through natural seed dispersal of cottonwood and bluejoint reedgrass.

Evaluation methods

Soil coverage was broadly estimated using aerial photographs. Floodplain woody debris was counted in July 2008 for the entire project area. Vegetation species and abundance was evaluated by using records of what was planted, observations of the success of planted vegetation, and surveys of several permanent plots that measured growth and composition.

Results

Soil cover

Rich organic soil taken from the forests surrounding the project area was spread over about 50% of the newly created floodplains to a depth of several inches. Imported organic soil was spread over about 5% of the floodplains. A mixture of clay, sand, gravel, and cobble was spread over about 30% of the floodplains, mostly on the eastern side of the main channel. No soil was spread on about 15% of the floodplains, leaving exposed gravel and cobble. Soil was not spread far enough down to the edge of the main channel in places.

In the areas where natural organic soils were not available, clay-rich sediment was spread on the floodplains in an attempt to provide fine-grained substrate to help establish a better medium for vegetation growth. This clay-rich soil was compacted in places from machinery, creating a very hard, cemented surface after restoration. These compacted, clay-rich areas create difficult conditions for planting vegetation. It would have been more desirable to till the areas of compacted soil immediately following restoration.

Floodplain woody debris

A 2008 count of floodplain woody debris showed a total of 545 pieces of floodplain wood throughout the entire project area. This does not include the in-channel woody debris. Over a floodplain area of 19.5 acres (not including the stream channels), the project area contains about 28 pieces of floodplain woody debris per acre of floodplain.

The majority of the floodplain wood (459 pieces) is less than 12 inches in diameter, while the remainder (86 pieces) is larger than 12 inches in diameter.

Restoration of the project reach greatly increased the amount of woody debris on the floodplain, but did not achieve the objective of 120 pieces per acre. While 120 pieces per acre would be beneficial in places, it is not as critical to achieve this density of wood in all of the upper floodplains. Floodplain wood is denser in some areas such as the areas near logjams, while other areas on the upper floodplains are relatively sparse (**figure 2.11**, **figure 2.12**). The majority of the large trees taken from the forest were used in construction of the logjams, and less emphasis was made on placing floodplain woody debris. Natural recruitment of woody debris will increase these numbers in the long term.

Figure 2.11: Dense concentrations of floodplain wood along Channel 1. Photo point 54, August 27, 2008.

Figure 2.12: Typical sparse concentrations of floodplain wood on the main channel upper floodplains. Photo Point 16, July 8, 2008.

Vegetation composition

Vegetation planted in the floodplains of the project area included spruce seedlings, birch seedlings and saplings, and willow cuttings. About 3 birch seedlings were planted for every spruce seedling on the floodplain (**table 2.7**). Willow cuttings were planted only along the streambanks, where the bottoms of the cuttings could extend into the water table. All of the plantings to date have had a survival rate of greater than about 95%.

While the project objectives are for 50% of the riparian tree composition to be spruce, re-vegetation of a disturbed area requires initial growth of pioneer species such as birch and cottonwood. Natural colonization of cottonwood on the floodplain is occurring rapidly, with numerous seedlings observed in 2008 from 10 to 40cm in height and distributed in clumps across the landscape (**figure 2.13**). While cottonwood and birch will likely become the dominant species on the floodplain in the short term, spruce will become more dominant in the long term. It is expected that with the establishment of a variety of tree species and the presence of mature trees in portions of the project area, a natural riparian ecosystem will develop.

Table 2.7: Species and numbers of plantings on banks and floodplains, 2006-2008.

Tree Species	2006	2007	2008	Total
Birch	4,000	1,800	900 (*est*)	6,700
Spruce	600	1000	500 (*est*)	2,100
Willow	4,000	4,000	1,000 (*est*)	9,000

Figure 2.13: Natural regeneration through seed dispersal of cottonwood has resulted in dense cover of cottonwood seedlings in portions of the project area in 2008.

Numerous grasses and forbs have also become established to provide from 15 percent to greater than 75 percent ground cover across the disturbed sites. A major portion of these species were likely contained as plants and seeds in the topsoil obtained from adjacent sites and spread across the disturbed area. Seeds of native grasses and forbs were broadcasted across some sites, but it has not been determined at this time whether these seeds have had a significant effect.

Many of the isolated mature spruce trees along the floodplains of the project area have died since completion of the project. This may be the result of changes in the water table elevation, physical damage to the trees, or increased susceptibility to spruce bark beetles, which have infested spruce trees in the surrounding areas. These dead spruce will may eventually provide wildlife habitat, nutrients, or in-stream woody debris.

2.7 Summary of Objectives

Table 2.8: Summary of objectives and results 3 years after completion of the restoration.

	Stated objective	**Result**
Floodplains	Increase entrenchment ratio from 1:1 to 6:1	Increased entrenchment ratio from 1:1 to an average of about 1:4
Channel pattern	Increase channel length by 15%	Increased channel length by 920 ft (18% increase).
	Increase sinuosity from 1.1 to 1.4	Increased sinuosity from 1.07 to 1.26 (18% increase).
Channel profile	Decrease average channel slope from 1.5% to 1.1%	Decreased average channel slope from 1.5% to 1.3% (15% decrease). Decreased slope of lower half of reach from 1.6% to 1.3%.
	Increase number of pools per mile from about 3 to 23.	Increased the number of pools per mile from about 3 to about 10 over the length of the restored reach. 15 pools per mile exist within the lower 3500 feet of the reach.
Side channels	Increase the percentage of the total flow in side channels from <1% to 5-20%	Constructed 15 side channels: 9420 feet of channel and 2.1 acres of ponds. 5 to 34% of flow in side channels upstream of Palmer Creek confluence, 1 to 5% of flow in side channels downstream of Palmer Creek confluence.
Aquatic habitat	Increase the amount of available spawning habitat from 160 to about 2000 square yards per river mile	Increased available spawning habitat to about 1350 square yards per stream mile.
	Increase the amount of large in-stream wood from 8 to 330 pieces per river mile	Increased woody debris to 346 pieces per river mile (only 27% of woody debris is greater than 12 inches in diameter)
Riparian vegetation	Restore topsoil to at least 80% of the floodplain	Restored organic soil to about 55% of the floodplains, and clay-rich soil to another 30% of the floodplains.
	Increase woody debris on the floodplain from 16 to 120 pieces per acre	Increased floodplain woody debris to an average of only about 28 pieces per acre.
	Restore tree composition to 50% spruce, 40% cottonwood, and 10% birch, and re-establish ground cover.	Planted of thousands of seedlings (75% birch and 25% spruce). Abundant natural regeneration of cottonwood. This early successional composition will grow into the desired composition in the long term.

3 CHANNEL AND FLOODPLAIN RESPONSE TO RESTORATION

3.1 Streamflows

Historic streamflows from 2005 to 2008 are important to consider because floods can potentially cause dynamic channel changes and adjustments in newly restored stream channels. No active stream gauges exist on Resurrection Creek. However, streamflows measured on Resurrection Creek in 2005 and 2006 have been shown to roughly correspond to streamflows in Sixmile Creek (MacFarlane, 2007), where a USGS gauge monitors daily streamflows (US Geological Survey, 2008). No streamflow information was collected on Resurrection Creek in 2007 or 2008. Although Resurrection Creek and Sixmile Creek are in adjacent watersheds, the Sixmile Creek watershed receives more abundant precipitation than Resurrection Creek, glaciers cover about 5% of the Sixmile Creek watershed compared to none in the Resurrection Creek watershed, and the Sixmile Creek watershed is 234 square miles compared to the 149 square mile Resurrection Creek watershed.

May through October flow data from 2005 to 2008 on Sixmile Creek give a good perspective of the magnitudes of flows the project area may have experienced since restoration began (**figure 3.1**). The 2-year recurrence flow on Sixmile Creek is estimated to be 4840 cfs and the 5-year recurrence flow estimate is 6290 cfs (Curran et al., 2003). Instantaneous peak flows on Sixmile Creek from 2005 to 2008 ranged from 4140 cfs to 5540 cfs, corresponding to flows with recurrence intervals of 1 to 5 years. It is likely that Resurrection Creek also experienced streamflows with recurrence intervals of 1 to 5 years between 2005 and 2008. Peak flows occurred between mid-May and early July in the 4 years since 2005. Although fall rainstorms produced some higher flows, peak flows always occurred as a result of summer snowmelt runoff.

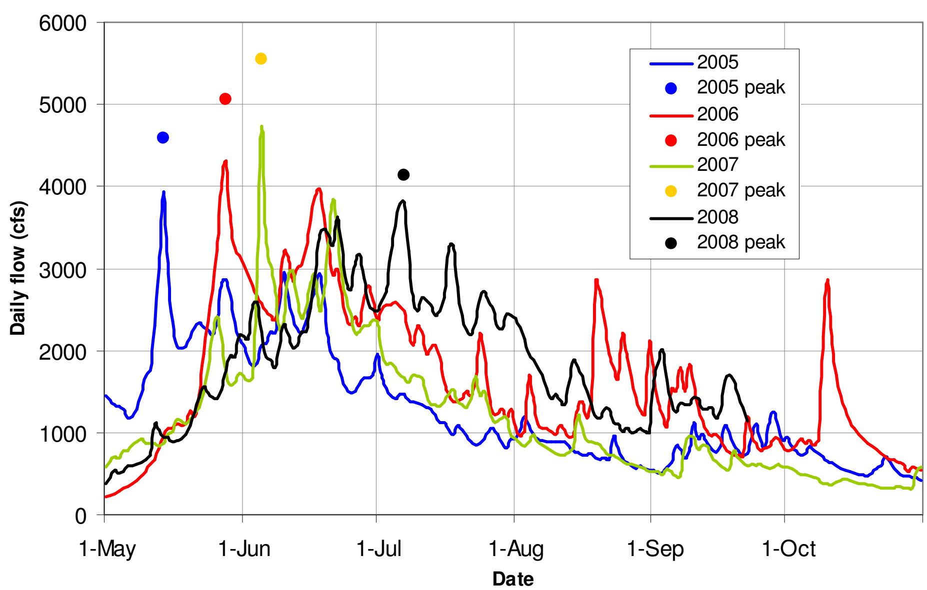


Figure 3.1: Average daily and instantaneous peak streamflows on Sixmile Creek, May through October 2005 through 2008 (data from US Geological Survey, 2008).

No peak flows greater than a 5-year magnitude have occurred on Resurrection Creek between 2005 and 2008. One of the highest flows during this period occurred during the beginning of the 2006 construction season. This actually provided a good opportunity to identify and alleviate flood concerns during construction of the channel. The lack of high magnitude flows following restoration has allowed the banks to stabilize somewhat with new riparian vegetation that will help provide stability when high flows do occur. However, the absence of high magnitude flows has limited the sediment transport, scour, and deposition that are needed to adjust the channel to more natural conditions, enhance spawning and rearing habitat, and deposit sediment and nutrients on the floodplains. As a result of the somewhat normal flows during this period, changes in the Resurrection Creek channel following restoration have been limited.

3.2 Channel survey methods

Stream channel morphology was surveyed using standard stream survey methodologies (Harrelson et al., 1994; Rosgen, 2006). Cross sections were surveyed by measuring the ground and stream bed elevations between permanent rebar pins established during previous monitoring years (2005-2007). Elevations were measured using a laser level and rod. By convention, the left bank signifies the left bank as looking downstream. Bankfull elevations were measured based on indicators or were estimated based on channel design. The floodprone elevation is defined as twice the maximum bankfull depth. Substrate was characterized for each riffle and glide cross section. Substrate size was characterized for both the active channel (from bottom of bank to bottom of bank) as well as for the bankfull channel (from bankfull to bankfull). For each pebble count, the intermediate axes of at least 100 individual particles were measured in a narrow swath at each cross section. Cross section locations were marked on aerial photography. Stream survey data were analyzed using RIVERMorph Stream Restoration Software (RiverMorph LLC, 2004).

3.3 Channel dimension data

Channel morphology surveys were conducted in the project area to provide baseline data for future change, characterize the restored channel, and evaluate whether the project objectives were met. A total of 24 cross sections and 3 longitudinal profiles were established in 2005 and 2006 on the main channel, Channel 1, and the lower portion of Palmer Creek (**table 3.1**). A number of these were re-surveyed in 2007 and 2008 to assess the response of the stream channels to the restoration.

Data analyses are presented in this chapter, and raw survey data for the 2008 surveys are presented in **Appendix A**. Trend comparisons are made using previous monitoring data collected in 2005 - 2007. Refer to previous monitoring reports (MacFarlane, 2006; MacFarlane, 2007) for the 2005 - 2007 raw data and additional analyses.

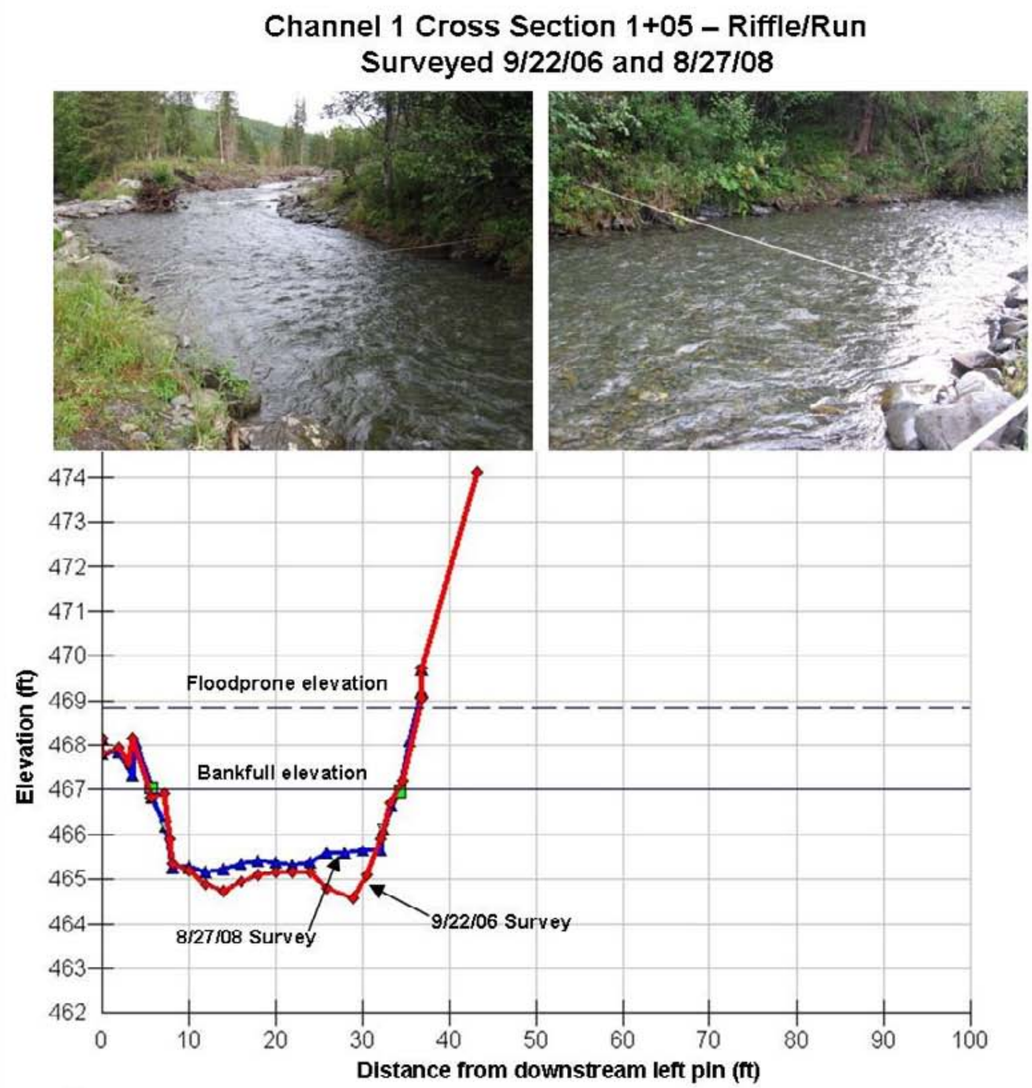
Table 3.1: Survey schedule of cross sections in the Resurrection Creek project area.

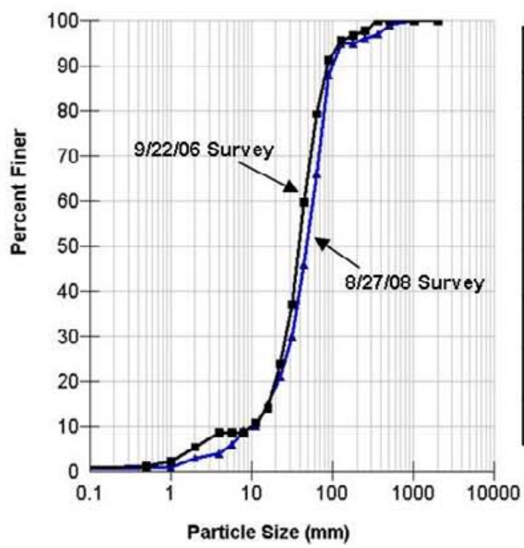
	Survey	2005	2006	2007	2008
Main Channel	XS 8+90 (riffle)	Established	-	Resurveyed	-
	XS 12+40 (glide)	Established	-	Resurveyed	-
	XS 12+73 (pool)	Established	Lost pin	-	-
	XS 14+82 (riffle)	Established	-	Resurveyed	-
	XS 15+38 (glide)	Established	-	Resurveyed	-
	XS 15+76 (pool)	Established	-	Resurveyed	-
	XS 17+05 (run)	-	Established	-	-
	XS 18+35 (run)	Established	-	-	-
	XS 24+97 (pool)	Established	Lost pin	-	-
	XS 30+96 (pool)	Established	Lost pin	-	-
	XS 40+30 (pool)	Established	-	-	-
	XS 42+60 (pool)	Established	Lost pin	-	-
	Upper Valley XS	-	Established	-	-
	Longitudinal Profile	Established	-	-	-
Channel 1	XS1+05 (riffle/run)	-	Established	-	Resurveyed
	XS 4+33 (riffle)	-	Established	-	Resurveyed
	XS 5+55 (glide)	-	Established	-	Resurveyed
	XS 7+07 (pool)	-	Established	-	Resurveyed
	XS 9+18 (riffle)	-	Established	-	-
	XS 13+79 (riffle)	-	Established	-	-
	Longitudinal Profile	-	Established	-	-
Palmer Creek	XS 1+46 (riffle)	-	Established	-	Resurveyed
	XS 3+61 (glide)	-	Established	-	Resurveyed
	XS 5+21 (riffle)	-	Established	-	Resurveyed
	XS 6+47 (riffle)	-	Established	-	-
	XS 7+22 (pool)	-	Established	-	-
	Longitudinal Profile	-	Established	-	-

Channel 1: 2008 data

Channel 1 is an 1825-foot long side channel in the upper portion of the project area, typically carrying up to 20% of the flow of Resurrection Creek. A total of 6 cross sections and a longitudinal profile were surveyed in Channel 1 in 2006 to characterize the channel and provide baseline data for evaluating channel changes (**figure 3.2**). These cross sections and characterization are presented in MacFarlane (2007). In 2008, 4 of these cross sections were re-surveyed to evaluate changes in the channel dimensions that have occurred in the channel in the first 2 years after construction (**figure 3.3, figure 3.4, figure 3.5, figure 3.6**).

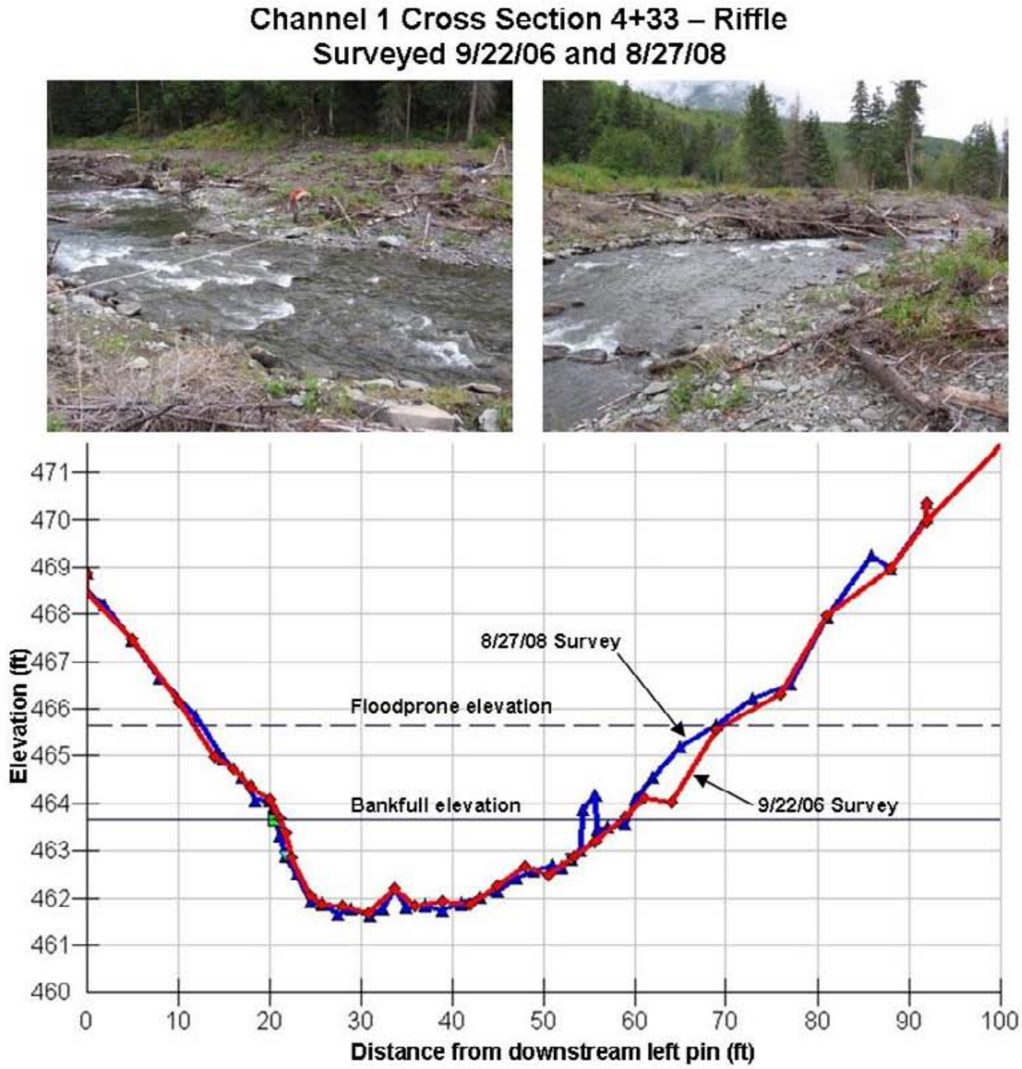
Figure 3.2: Channel 1 cross section locations.

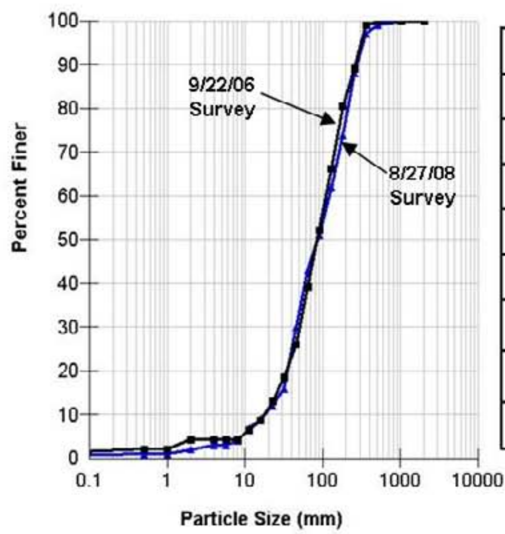




	9/22/06	8/27/08
Bankfull width	28.3 ft	28.7 ft
Avg. bankfull depth	1.7 ft	1.4 ft
Bankfull XS Area	47.3 ft^2	41.3 ft^2
Max. bankfull depth	2.3 ft	1.9 ft
Width/Depth ratio	17	20
Entrenchment ratio	>2	>2
D50 (active channel)	39 mm	49 mm
D84 (active channel)	74 mm	85 mm

Figure 3.3: Changes in Channel 1 cross section 1+05 (riffle/run) from 2006 to 2008.

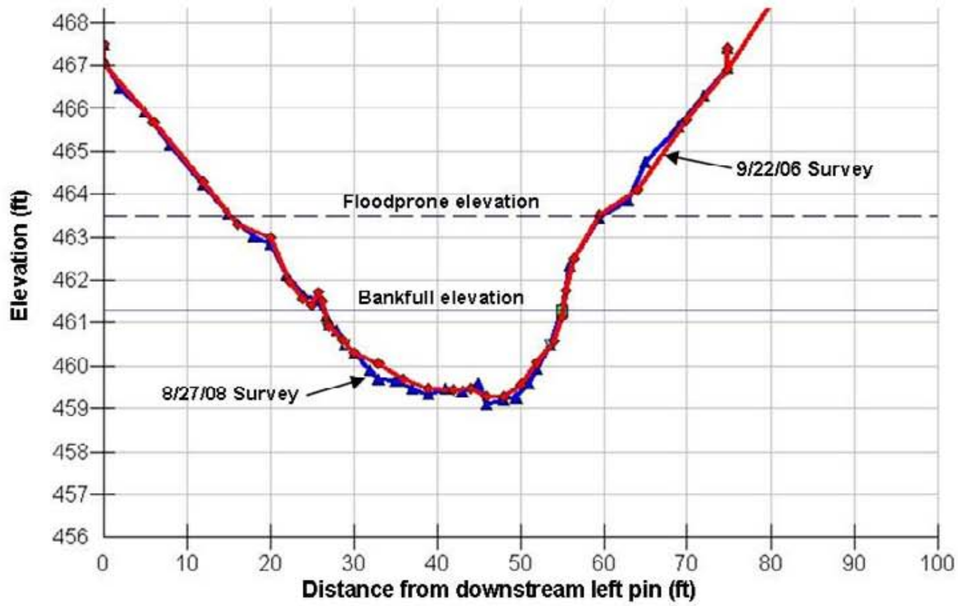


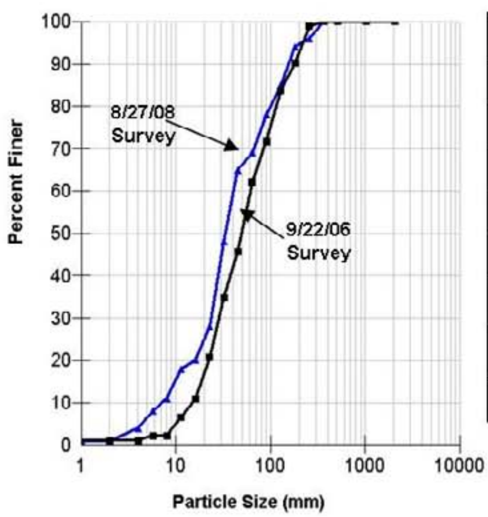


	9/22/06	8/27/08
Bankfull width	38.0 ft	36.9 ft
Avg. bankfull depth	1.4 ft	1.4 ft
Bankfull XS Area	52.1 ft^2	50.9 ft^2
Max. bankfull depth	2.1 ft	2.0
Width/Depth ratio	28	27
Entrenchment ratio	1.6	1.5
D50 (active channel)	86 mm	87 mm
D84 (active channel)	211 mm	234 mm

Figure 3.4: Changes in Channel 1 cross section 4+33 (riffle) from 2006 to 2008.

Channel 1 Cross Section 5+55 – Glide
Surveyed 9/22/06 and 8/27/08

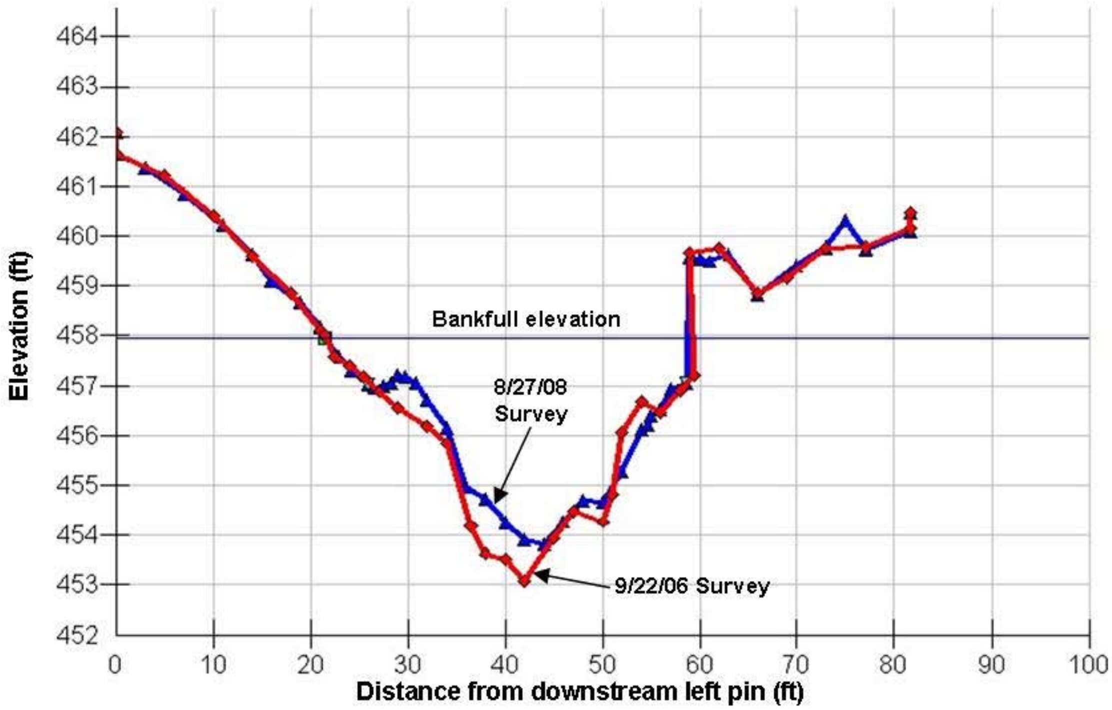




	9/22/06	8/27/08
Bankfull width	30.0 ft	28.7 ft
Avg. bankfull depth	1.6 ft	1.5 ft
Bankfull XS Area	47.0 ft^2	43.3 ft^2
Max. bankfull depth	2.2 ft	2.2
Width/Depth ratio	19	19
Entrenchment ratio	1.6	1.5
D50 (active channel)	50 mm	34 mm
D84 (active channel)	130 mm	123 mm

Figure 3.5: Changes in Channel 1 cross section 5+55 (glide) from 2006 to 2008.

Channel 1 Cross Section 7+07 – Pool
Surveyed 9/22/06 and 8/27/08



	9/22/06	8/27/08
Bankfull width	37.8 ft	37.2 ft
Avg. bankfull depth	2.5 ft	2.2 ft
Bankfull XS Area	94.9 ft^2	82.4 ft^2
Max. bankfull depth	4.9 ft	4.1
Width/Depth ratio	15	17

Figure 3.6: Changes in Channel 1 cross section 7+07 (pool) from 2006 to 2008.

Palmer Creek: 2008 data

Palmer Creek is a major tributary that drains a 21-square mile watershed and joins Resurrection Creek in the upstream half of the project reach. During the 2006 construction season, the lower 850-foot reach of Palmer Creek (in the Resurrection Creek floodplain to the confluence with Resurrection Creek) was reconstructed (**figure 3.7**). Channel morphology surveys were conducted on Lower Palmer Creek in 2006 to characterize the dimensions, pattern, and profile of the channel, and provide baseline data to measure changes in channel form. In 2008, 3 of the cross sections were re-measured to evaluate channel changes that have occurred in the first 2 years since restoration was completed on this channel (**figure 3.8, figure 3.9, figure 3.10**).

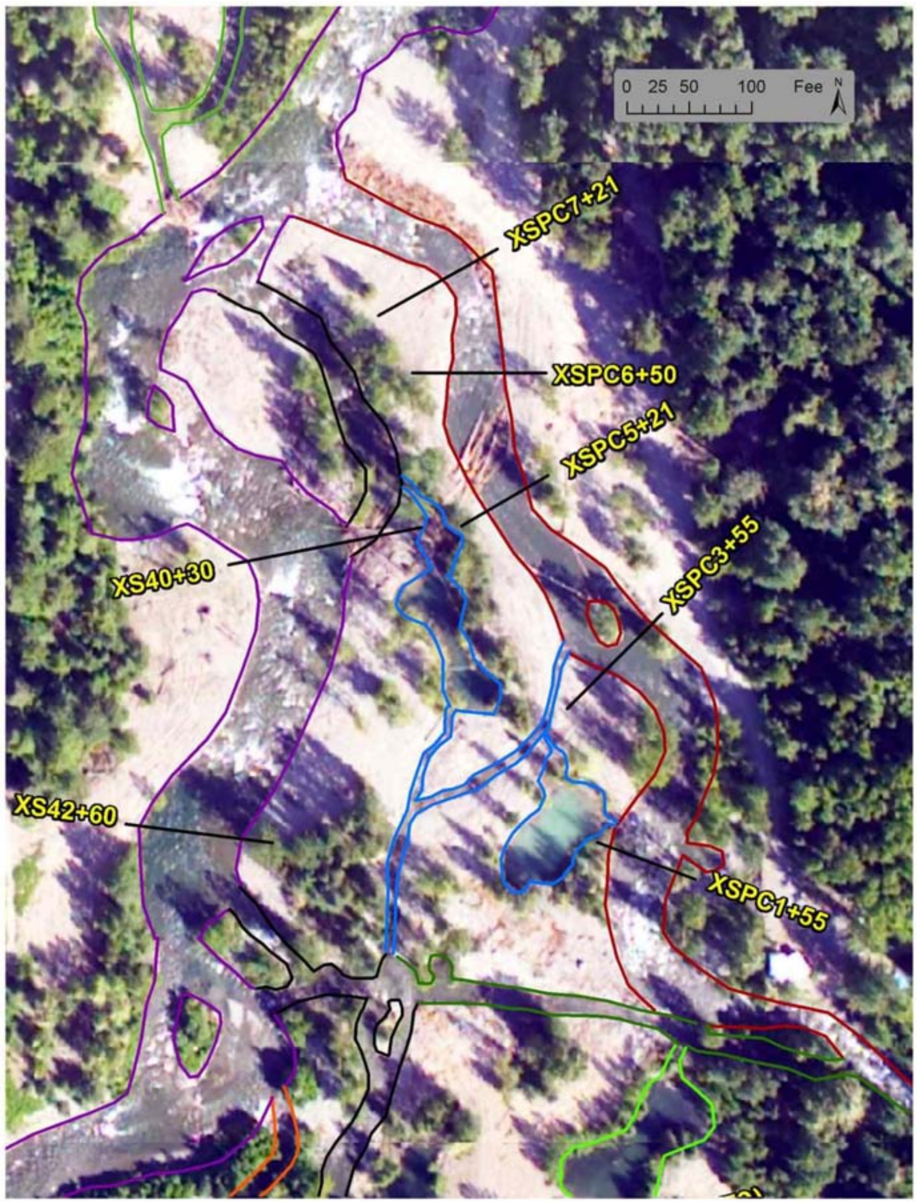
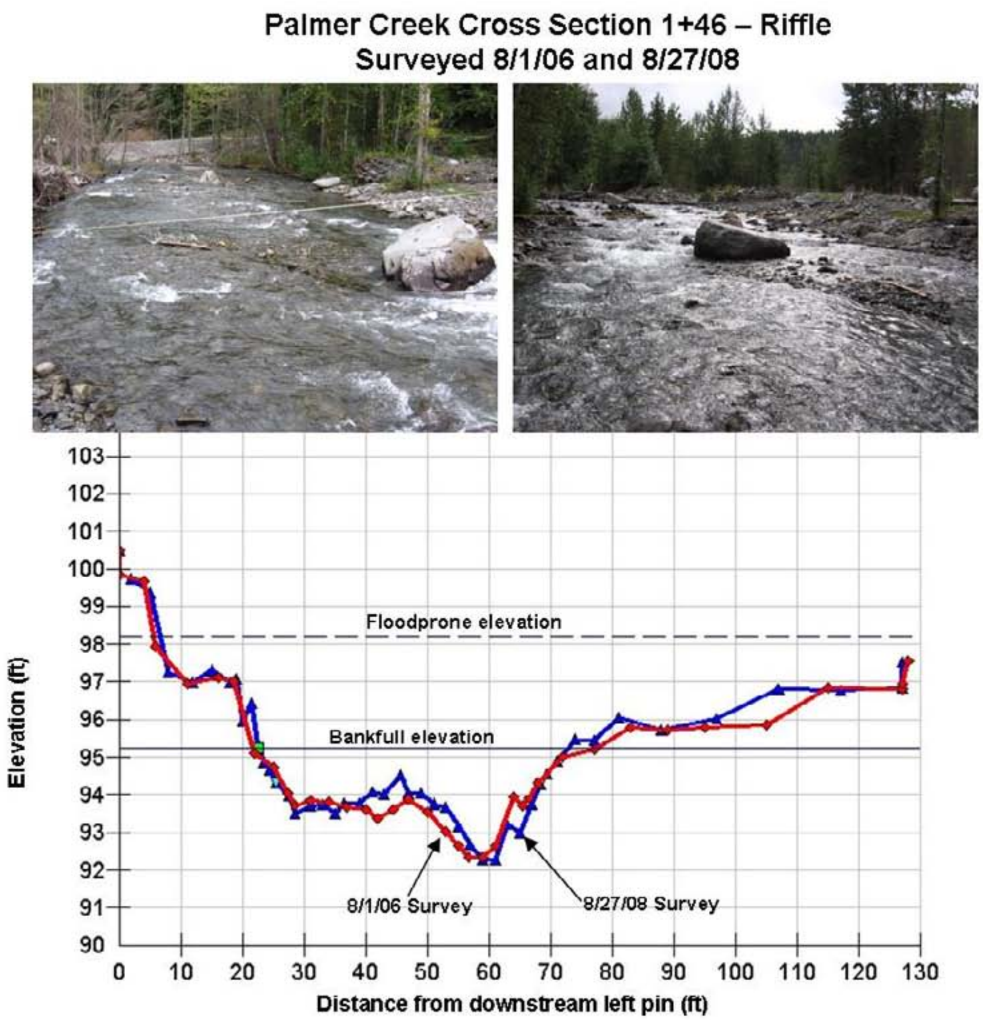
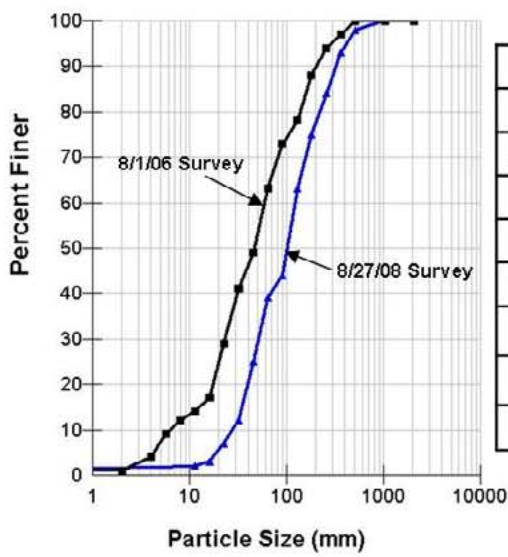


Figure 3.7: Palmer Creek cross section locations.

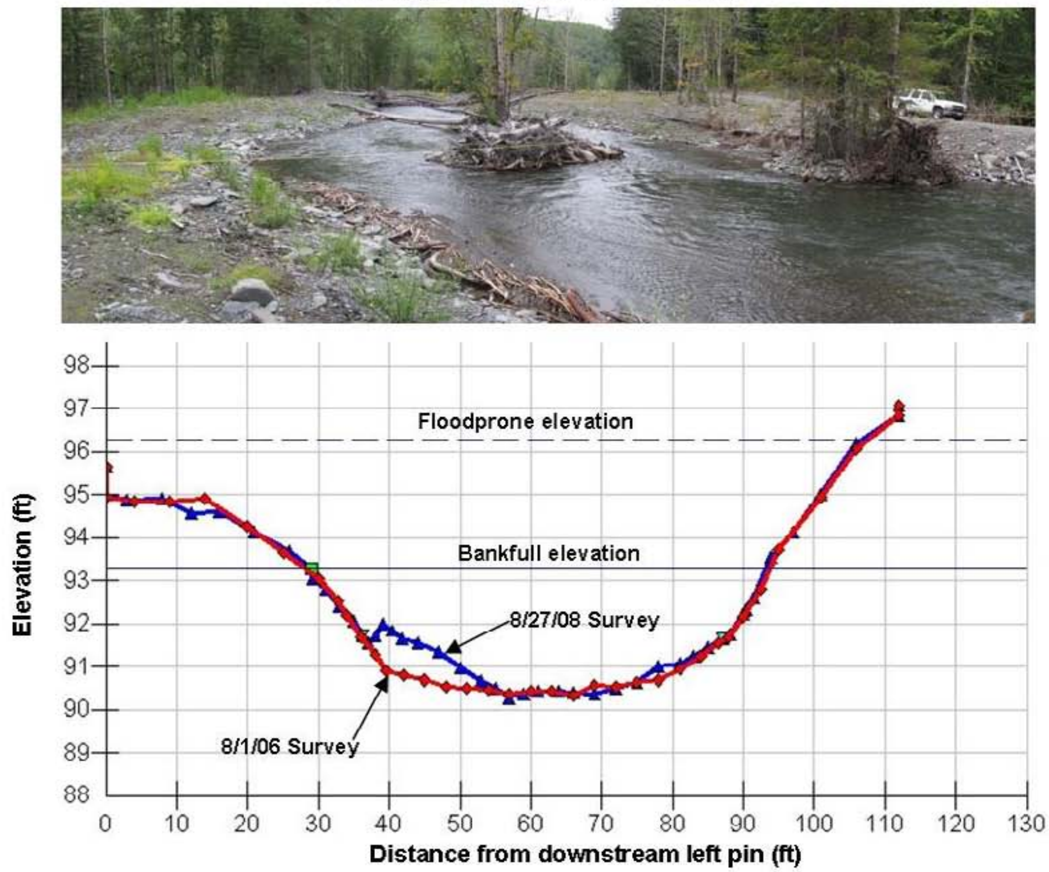


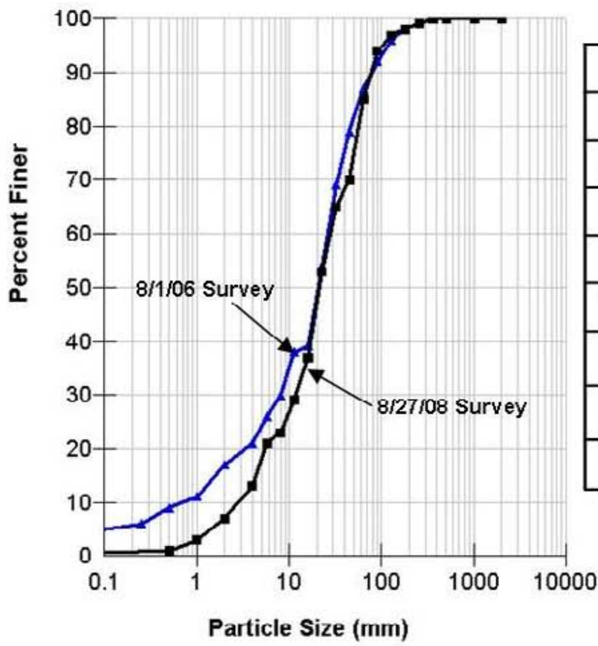


	8/1/06	8/27/08
Bankfull width	48.1 ft	50.3 ft
Avg. bankfull depth	1.4 ft	1.5 ft
Bankfull XS Area	66.4 ft^2	75.1 ft^2
Max. bankfull depth	2.7 ft	3.0 ft
Width/Depth ratio	35	34
Entrenchment ratio	>2.5	>2.5
D50 (active channel)	46 mm	102 mm
D84 (active channel)	159 mm	256 mm

Figure 3.8: Changes in Palmer Creek cross section 1+46 (riffle) from 2006 to 2008.

Palmer Creek Cross Section 3+61 – Glide
Surveyed 8/1/06 and 8/27/08

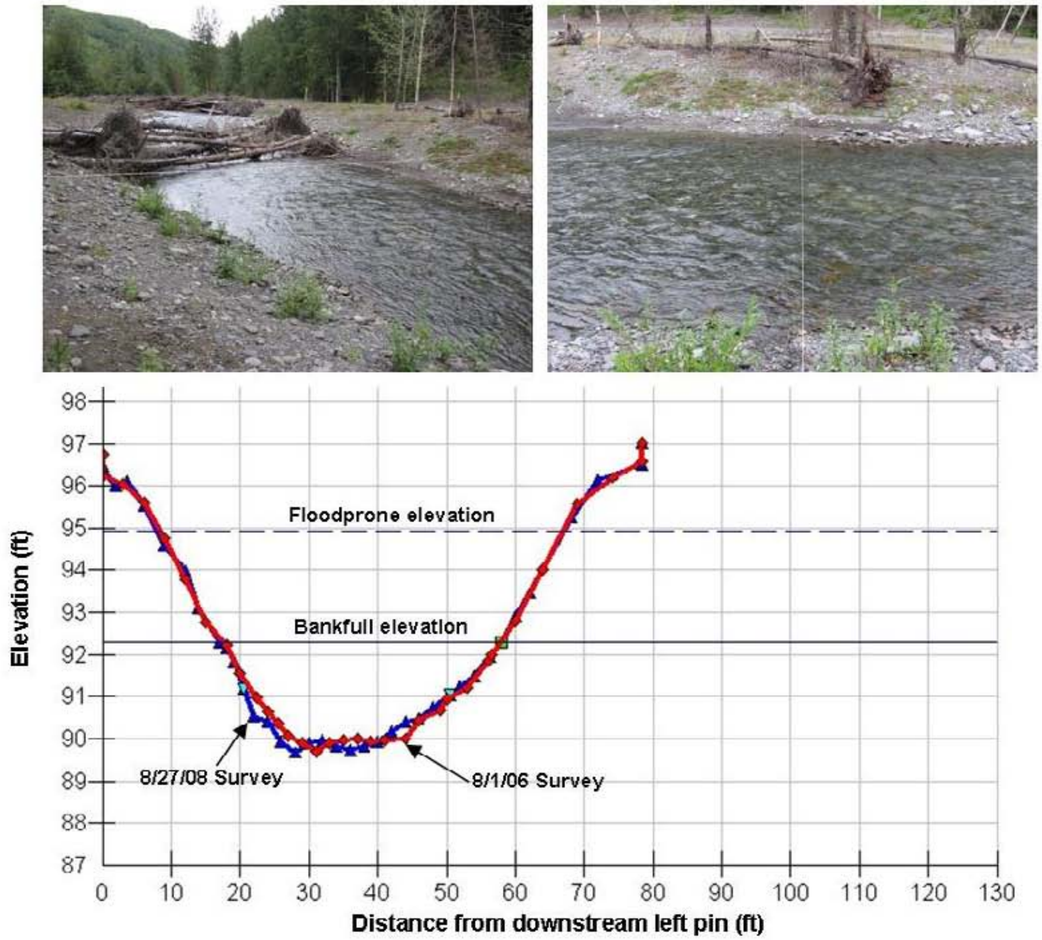


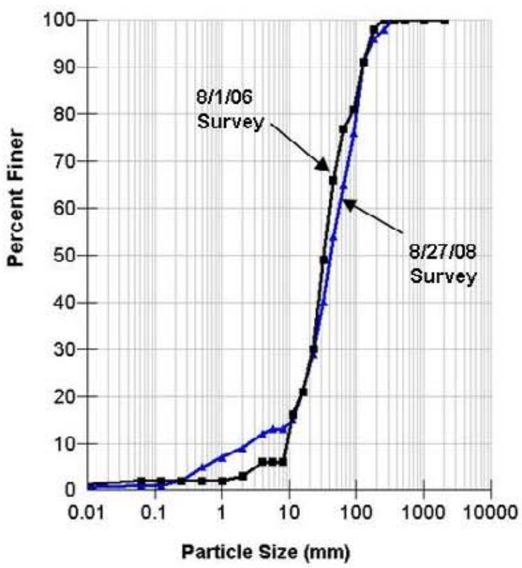


	8/1/06	8/27/08
Bankfull width	58.7 ft	64.3 ft
Avg. bankfull depth	1.7 ft	2.0 ft
Bankfull XS Area	97.0 ft^2	130.7 ft^2
Max. bankfull depth	2.2 ft	3.0 ft
Width/Depth ratio	36	32
Entrenchment ratio	1.4	1.7
D50 (active channel)	21 mm	21 mm
D84 (active channel)	63 mm	57 mm

Figure 3.9: Changes in Palmer Creek cross section 3+61 (glide) from 2006 to 2008.

Palmer Creek Cross Section 5+21 – Riffle
Surveyed 8/1/06 and 8/27/08





	8/1/06	8/27/08
Bankfull width	37.9 ft	41.1 ft
Avg. bankfull depth	1.5 ft	1.7 ft
Bankfull XS Area	57.6 ft^2	71.0 ft^2
Max. bankfull depth	2.3 ft	2.6 ft
Width/Depth ratio	25	24
Entrenchment ratio	1.4	1.4
D50 (active channel)	33 mm	41 mm
D84 (active channel)	101 mm	110 mm

Figure 3.10: Changes in Palmer Creek cross section 5+21 (riffle) from 2006 to 2008.

3.4 Channel change trends

Main Channel

Of the 13 cross sections established on the main channel in 2005 (MacFarlane, 2006), 5 were re-surveyed 2 years later in 2007 (MacFarlane, 2007). The endpoint pins for 4 of these cross sections were lost during additional restoration activities in 2006 and may not be able to be accurately re-surveyed in the future. None of these cross sections were re-surveyed in 2008 because of persistent high flows and difficulties in crossing the channel. A longitudinal survey was surveyed in 2005 but has not been re-surveyed. Channel characterization of the main channel is presented in the 2005 and 2006-2007 monitoring reports (MacFarlane, 2006; MacFarlane, 2007).

Few additional changes have occurred between 2007 and 2008 in the main channel. This is likely the result of increasing bank stability and the lack of high magnitude floods. The portion of the western bank along Meander 2 (at XS 8+90) that saw relatively high erosion rates in 2006 and 2007 showed very little additional erosion in 2008. Two of the steeper riffles within the project reach that indicated some gradient adjustments in 2006 and 2007 (at Meander 2 and Meander 5) appear to have stabilized somewhat in 2008. Logjams have remained stable, although the west bank logjam in the Meander 2 riffle has been undercut somewhat because of the high velocity flows directed into the logjam (**figure 3.11**). This area may experience additional changes during the next high flow event.

Figure 3.11: Bank cutting behind the Meander 2 logjam on the west bank.

Channel 1

Channel 1 has remained relatively stable since these channels were created in 2006. Many of the riffles were constructed with oversized cobbles and boulders. While this does not allow for bedload movement as would occur in a natural channel, it does provide for increased channel stability. Riffle cross sections showed very little change between 2006 and 2008. Some deposition has occurred in glides and pools, but the channel dimensions have generally not changed. Because Channel 1 does not experience high magnitude flows, even when flows in the main channel are high, this side channel will remain relatively stable.

Palmer Creek

The lower portion of Palmer Creek that was reconstructed in 2006 has adjusted somewhat. The transition area where the channel descends steeply onto the flat Resurrection Creek floodplain has seen some deposition. Gravel and sand deposition has occurred in a long section of glides and runs in this area, and numerous spawning salmon utilize this portion of the channel. The lower 2 riffles in Palmer Creek were constructed using oversized material. As in Channel 1, these don't allow for bedload movement, but do provide channel stability. The logjams in Palmer Creek have remained stable. Only a small amount of bank erosion has occurred around the cross-channel logjam. Additional erosion may be expected at this location because of the decreased cross sectional area caused by the logs occupying the channel.

3.5 Evaluation of success and growth rates of planted vegetation

An inventory of the plant establishment success was conducted in June and August of 2008 to determine the level of survival for those plants established in 2007 and continued success of those planted in 2006. Seedlings and cuttings planted in 2008 were monitored in August by Dean Davidson and Dan Svoboda to obtain some preliminary results. All of the planting was conducted through the efforts of the Youth Restoration Corps (YRC).

All revegetation efforts have been directed toward the acceleration of native plant establishment that typify the appropriate plant species at the early successional stage on the floodplain in Resurrection Creek. Plant species used were based on the soil and hydrologic conditions of the planting sites. Major woody species included Alaska paper birch (*Betula paperiferica*), White/Lutz spruce (*Picea X lutzii*), feltleaf willow (*Salix alaxensis)*, Sitka willow (*Salix sitchensis*), undergreen willow (*Salix commutate*), and barclay willow (*Salix barclayi*). Native seeds of grasses and forbs collected in the local area and obtained under a contract from the Plant Materials Center in Palmer, Alaska were also broadcasted on some of the sites in 2006.

In 2007, about 10 acres were planted in the upper project area, including the area around Palmer Creek, Channel 1, and the Upper Reach Split Channel. This planting effort included about 4,000 dormant willow cuttings, 1,000 white spruce seedlings, 300 18-month old birch, and 1,500 6-month old birch. In addition, 150 feet of sod and willow wraps were constructed along the banks of side channels, and 500 to 1000 sod transplants were planted. Most of the planting that was completed in 2008 consisted of planting willows near the river that had previously been missed, and planting 6-month old birch and spruce in areas not previously planted.

All of the planted spruce and birch seedlings from 2006 to 2008 continue to have a successful establishment above 95 percent. The birch seedlings, regardless of the age at planting, are growing in height and branches. The only exception has been where they were covered by ice during the first year after planting. The 6-month old birch seedlings planted in June of 2008 had lost their leaves, but appear to have set new buds. This is similar to what happened to those planted in 2007, which in 2008 they all appeared to have survived and starting to grow. Those planted in 2008 will be monitored again in 2009 to verify successful establishment.

The spruce seedlings (*Picea X luzii*) from all three years of planting also appear to be successful. The spruce seedlings planted in 2006 and 2007 were put into the top soil at about a 30° angle to maximize the amount of top soil around the root zone. These seedlings have now grown to a vertical orientation. Those planted in 2006 were very green and putting on new branches and height. Those planted in 2007 had also put on new branches and height, but were yellow in color. These were all fertilized with an all purpose, slow release organic fertilizer and given an application of compost tea in June of 2008 and by August of 2008 they had obtained a healthy green color and were putting on continued new growth.

All three species of willows (feltleaf, Sitka, undergreen, and barclay) planted in 2006 and 2007 continue to have a greater than 95 percent successful rate. It is difficult to measure growth because the moose browsed many of the plants during the winter of 2007-2008. Those willows planted in 2008 grew from 20 to 30 cm during the summer up through August (**figure 3.12**). The planting techniques which included having the base of the willow cutting at or below the water level at low summer flow, putting six inches of fine textured soil in the hole around the cutting, and covering that with gravel and cobbles for protection, has produced outstanding success with all four species.

Naturally invading Cottonwood (*Populus balsamifera* subsp.*balsamifera* and *trichocarpa*), as expected from the numerous trees adjacent and within the site, made its entry into the project area in 2007. Seedling establishment, mostly in clumps rather than distributed evenly across the landscape, will definitely become the major tree species. In 2008, cottonwood seedlings ranged from 10 to 40 cm in height (**figure 2.13**).

Numerous grasses and forbs have also become established to provide from 15 percent to greater than 75 percent ground cover across the disturbed sites (**figure 3.13**). A major portion of these species were likely contained as plants and seeds in the topsoil obtained from adjacent sites and spread across the disturbed area. Seeds of native grasses and forbs were broadcasted across some sites, but it has not been determined at this time whether these seeds have had a significant affect.

Figure 3.12: Willow stakes planted along Channel 1 in June 2008 (8-28-08 photo).

Figure 3.13: Naturally regenerated bluejoint reedgrass along Meander 5 (9-29-08 photo).

3.6 Vegetation growth rates, composition, and cover

Surveys of vegetation transects from 2006 to 2008 were conducted by Rob DeVelice, Forest Ecologist, with assistance from Dean Davidson, Chris McKee, and Martin Bray in establishment and initial readings of the monitoring transects. Also assisting in reading the transects were Dan Svoboda, Kate Mohatt, members of the Youth Restoration Corps, and students of the Hope (Alaska) School.

As part of the Resurrection Creek Phase I Restoration project on the Kenai Peninsula, Alaska, soil was spread over areas of former mine tailings to enhance re-vegetation. Of interest are the rate, composition, and cover of vegetation recovery in the restoration area. Vegetation development was monitored annually over a three-year period in quadrats systematically spaced along six transects. Most of the sites in the Resurrection Creek Phase I Restoration Area where soil is abundant have experienced large increases in vegetation cover from 2006 to 2008. To date, non-native plant species constitute a small fraction (1%) of the vegetation cover. The potential for expansion of non-native invasive plants remains a concern since 24 non-native species have been documented in the greater project area. Vegetation development within the restoration area is summarized, based on three years of annual monitoring.

Methods

Systematic sampling of quadrats along transects (Elzinga et al. 1998) were used to estimate ground, life form, and species cover. Six transects were subjectively selected within the project area (**figure 3.14**) to represent variation in sites and including a "control" on a historic mine tailing (Transect 4). With the exception of Transect 4 (50 feet in length)[1], all transects were 100 feet long. The end points of each transect was permanently marked with reinforcing rods and wooden stakes. Quadrat frames 20 by 50 cm in size were read at 5 foot increments (beginning at 5 feet) along the right side of the transect line. The lower left corner of the frame was positioned at the 5 foot interval

[1] A historic mine tailing large enough to accommodate a 100 foot transect could not be found within the project area. The larger mine tailings had all undergone restoration.

point with the short axis of the frame parallel to the transect line. Canopy cover of vascular plant taxa was assessed by visually estimating the percent of a quadrat occupied by the vertical projection of each taxa onto the ground. Seven cover classes were recorded in the field and the midpoint cover percent was used in all analyses.[2] Ground cover was estimated for bare soil, gravel, cobble, stone, litter, wood, lichen, moss, and basal vegetation classes. Life form cover was estimated for forb, graminoid, shrub, and tree classes.

The primary data used in analyses was "sum cover" (i.e., the total of the cover estimates across quadrats on each transect). Data from individual quadrats were not analyzed separately. The difference in sum cover values across plant taxa between years was compared using the paired *t*-test (Steele and Torrie 1960; Elzinga et al. 1998). This test is appropriate since the data are repeat measurements from the same locations and are thus highly correlated. In addition, regression was used to summarize the trend in sum cover across years.

Figure 3.14: Layout of the six transects in the Resurrection Creek Restoration Area. Transect 4 is the "control" on a historic tailings pile.

[2] Cover classes (and midpoints) are: T – 0.1 to 1% (.5); 1 – 1 to 5% (3); 2 – 5 to 25% (15); 3 – 25 to 50% (37.5); 4 – 50 to 75% (62.5); 5 – 75 to 95% (85); and 6 – 95 to 100% (97.5).

Results and Discussion

A total of 50 vascular plant taxa were observed within the sample quadrats on the six transects (**table 3.2, table 3.3**). In order of abundance, the top five most abundant species observed were bluejoint reedgrass (*Calamagrostis canadensis*), tickle grass (*Agrostis scabra*), common horsetail (*Equisetum arvense*), tall fireweed (*Epilobium angustifolium*), and fowl bluegrass (*Poa palustris*). Species richness varied from a low of two on transect 3 in 2006 to a high of 24 on transects 5 and 6 in 2008 (**table 3.3**). Although only eight of the 50 taxa are non-native to Alaska (and represent just one percent of the total cover), 24 non-native plant species have been observed in the project area (R.L. DeVelice, unpublished data). The potential for expansion of non-native invasive plants remains a concern with the project area.

As can be seen from the transect photos (**figure 3.15 - figure 3.21**)[3] there is wide variation is the development of vegetation cover along the six transects between 2006 and 2008. Specifically, as summarized in **figure 3.22**, the largest increases in vegetation cover is on transects 1, 2, and 6 (**figure 3.15**, **figure 3.16**, and **figure 3.21**; respectively). The increase in cover on transect 5 is intermediate (**figure 3.20**). Only a slight increase has occurred on transect 3 and the transect 4 "control" (**figures 3.18** and **figure 3.19**, respectively). Other than the "control", transect 3 has the least amount of soil present (**figure 3.18**) which likely explains the slow rate of vegetation development. The only transect in which no statistically significant pair wise comparisons of cover occurred between years is the "control" (**table 3.3**).

Similar to canopy cover of vascular plant species, there is wide variation in ground cover (**figure 3.23**) and life form cover (**figure 3.24**) changes on the transects from 2006 to 2008. The largest ground cover change is the decline of bare soil cover on transects 1, 2, and 6 and a corresponding increase in litter cover (**figure 3.23**). Also on transects 1, 2, and 6 there are pronounced increases in the cover of forb and graminoid life forms (**figure 3.24**).

In summary, most of the sites in the Resurrection Creek Phase I Restoration Area where soil is abundant have experienced large increases in vegetation cover from 2006 to 2008. To date, non-native plant species constitute a small fraction (1%) of the vegetation cover on the transects.

[3] All transect photos look from the end towards the beginning of the transect.

Table 3.2. The 50 vascular plant taxa observed within sample quadrats on the six transects in the Resurrection Creek Phase I Restoration Area. "Sum cover" is the total of the individual taxa cover estimates across all quadrats. The eight taxa listed as "alien" are non-native to Alaska. The sum cover of alien taxa represents one percent of the total cover of all taxa recorded in the quadrats.

CODE	SCIENTIFIC NAME	SUM COVER	ALIEN
	TREES		
BETPAP	*Betula papyrifera* Marsh.	84	
PICLUT	*Picea* X *lutzii* Little	15.5	
POPBALT	*Populus balsamifera* ssp. *trichocarpa* (Torr. & Gray ex Hook.) Brayshaw	170.5	
	SHRUBS		
RIBES	*Ribes* L.	6	
ROSACI	*Rosa acicularis* Lindl.	108	
RUBIDA	*Rubus idaeus* L.	67	
SALIX	*Salix* L.	3	
SALBAR	*Salix barclayi* Anderss.	18	
SALSIT	*Salix sitchensis* Sanson ex Bong.	3	
	FORBS		
ARALYR	*Arabis lyrata* L.	222.5	
CHENOP	*Chenopodium* L.	0.5	Y
EPIADE	*Epilobium adenocaulon* Hausskn.	69	
EPIANG	*Epilobium angustifolium* L.	691.5	
EPILAT	*Epilobium latifolium* L.	6	
ERYCHE	*Erysimum cheiranthoides* L.	1	Y
GALTRIL	*Galium triflorum* Michx.	88.5	
GEUMAC	*Geum macrophyllum* Willd.	262	
MATDIS	*Matricaria discoidea* DC.	3.5	Y
MELALB	*Melilotus albus* Medik.	3	Y
PLAMAJ	*Plantago major* L.	4.5	Y
POLACU	*Polemonium acutiflorum* Willd. ex Roemer & J.A. Schultes	100.5	
POLYGO	*Polygonum* L.	3	Y
POTNOR	*Potentilla norvegica* L.	40.5	
RORIPP	*Rorippa* Scop.	3	
SAGSAG	*Sagina saginoides* (L.) Karst.	3	
STELLA	*Stellaria* L.	84	
STECAL	*Stellaria calycantha* (Ledeb.) Bong.	3	
STESIT	*Stellaria sitchana* Steud.	18.5	
TAROFF	*Taraxacum officinale* F.H. Wigg.	86.5	Y
THASPA	*Thalictrum sparsiflorum* Turcz. ex Fisch. & C.A. Mey.	0.5	
UCRUC	unidentified Cruciferae	3.5	
UFORB	unidentified forb	68	

GRAMINOIDS			
AGRSCA	*Agrostis scabra* Willd.	2215	
ALOAEQ	*Alopecurus aequalis* Sobol.	137	
BROMUS	*Bromus* L.	3	
CALCAN	*Calamagrostis canadensis* (Michx.) Beauv.	3048	
CAREX	*Carex* L.	16.5	
CARMED	*Carex media* R. Br.	65.5	
CINLAT	*Cinna latifolia* (Trev. ex Goepp.) Griseb.	15.5	
FESRUB	*Festuca rubra* L.	7.5	
HORBRA	*Hordeum brachyantherum* Nevski	0.5	
POA	*Poa* L.	1	
POAPAL	*Poa palustris* L.	511	
POAPRA	*Poa pratensis* L.	3	Y
TRISPI	*Trisetum spicatum* (L.) Richter	6	
UGRAM	unidentified graminoid	17.5	
FERNS AND FERN ALLIES			
EQUARV	*Equisetum arvense* L.	1950.5	
EQUPRA	*Equisetum pratense* Ehrh.	74	
EQUSYL	*Equisetum sylvaticum* L.	62	
GYMDRY	*Gymnocarpium dryopteris* (L.) Newman	15	

Table 3.3. Sum cover by taxa across all quadrats on each transect in each of the three years of monitoring. Highlighted sum cover values are those where average cover (sum cover/number of quadrats) is ≥ 5%. Also highlighted are cases where the probability of a greater value of t is less than 10% in pair wise comparisons of sum cover values. Codes are as listed in Table 3.2.

	Transect 1			**Transect 2**			**Transect 3**		
	2006	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**
TREES									
BETPAP		2	4	1	2	20		6.5	22
PICLUT		2.5	4		0.5	3.5		1.5	1
POPBALT		3.5	17.5			3.5		3.5	26
SHRUBS									
RIBES								3	3
ROSACI	1	18	45.5	4	18	18			
RUBIDA			4		6.5	6.5			
SALIX									3
SALBAR									
SALSIT									
FORBS									
ARALYR								3	1
CHENOP									
EPIADE			14		1.5	10.5			
EPIANG	18	150.5	199	8	84.5	49			3
EPILAT									
ERYCHE									

GALTRIL			3		15	3			
GEUMAC			15	15.5	52.5	71			
MATDIS									0.5
MELALB									
PLAMAJ		3				1.5			
POLACU		18.5	75						0.5
POLYGO									
POTNOR		3	37.5						
RORIPP	3								
SAGSAG								3	
STECAL				3.5	18	21.5			
STELLA									
STESIT			18.5						
TAROFF		0.5	15.5		3	3			
THASPA									
UCRUC									
UFORB	3	4.5	0.5	2.5			0.5	5.5	5.5

GRAMINOIDS

AGRSCA		21	30.5		93	85			3.5
ALOAEQ		3	1		2	16			0.5
BROMUS									
CALCAN	50	271	616.5	112.5	626	856		3	16
CAREX					1			0.5	15
CARMED									
CINLAT									
FESRUB	1.5								
HORBRA					0.5				
POA									
POAPAL		18	30		37.5	66			
POAPRA						3			
TRISPI									
UGRAM									0.5

FERNS AND FERN ALLIES

EQUARV	10.5	179.5	210.5	63	442	404	3		
EQUPRA		3				1		15	15
EQUSYL	4.5	4	3.5	8	37	2			
GYMDRY		3.5	4	0.5		1			
SUM	**91.5**	**709**	**1349**	**218.5**	**1440.5**	**1645**	**3.5**	**44.5**	**116**

	n	**t value**	**Pr > t**	**n**	**t value**	**Pr > t**	**n**	**t value**	**Pr > t**
06 vs 07	20	2.16	0.0434	20	2.01	0.059	11	2.77	0.198
06 vs 08	23	2.12	0.0457	22	1.81	0.085	17	3.15	0.0061
07 vs 08	23	1.87	0.0742	23	0.84	0.4113	18	2.33	0.0321

Table 3.3. (continued)

	Transect 4 ("control")			Transect 5			Transect 6		
	2006	**2007**	**2008**	**2006**	**2007**	**2008**	**2006**	**2007**	**2008**
TREES									
BETPAP					2	16		0.5	7.5
PICLUT								0.5	1
POPBALT					14	66.5		10	26
SHRUBS									
RIBES									
ROSACI									
RUBIDA		30.5	18			0.5			1
SALIX									
SALBAR						15			3
SALSIT						3			
FORBS									
ARALYR				0.5	3		30	167.5	17.5
CHENOP					0.5				
EPIADE						0.5		31	8
EPIANG	30	67.5	48						24
EPILAT						3			3
ERYCHE						1			
GALTRIL						0		6	61.5
GEUMAC						15		16.5	52.5
MATDIS						3			
MELALB						3			
PLAMAJ									
POLACU					3	3			0.5
POLYGO				3					
POTNOR									
RORIPP									
SAGSAG									
STECAL									
STELLA									3
STESIT									
TAROFF	30	18	15			1			0.5
THASPA					0.5				
UCRUC				0.5	3				
UFORB			3	10.5	14.5	0.5	2	11	2

GRAMINOIDS

AGRSCA				0.5	84	153		742	1002.5
ALOAEQ					19	16		72.5	6
BROMUS	3								
CALCAN					3	27	38.5	51	154.5
CAREX									
CARMED						1		22	42.5
CINLAT								0.5	15
FESRUB							6		
HORBRA									
POA						1			
POAPAL	18	31	61.5		7	74	0.5	42	95.5
POAPRA									
TRISPI		3	3						
UGRAM				4.5	8.5	4			

FERNS AND FERN ALLIES

EQUARV					3	15	14	194.5	199.5
EQUPRA						3.5		16	20.5
EQUSYL									
GYMDRY						0.5	0.5	1.5	3.5

SUM	**81**	**150**	**148.5**	**19.5**	**165**	**426**	**91.5**	**1385**	**1750.5**
	n	**t value**	**Pr > t**	**n**	**t value**	**Pr > t**	**n**	**t value**	**Pr > t**
06 vs 07	6	1.46	0.2054	15	1.78	0.0972	18	1.75	0.0989
06 vs 08	7	1.35	0.2256	27	2.34	0.0274	25	1.66	0.1106
07 vs 08	7	-0.04	0.9724	28	2.42	0.0226	25	1.08	0.2901

Figure 3.15: Conversion from bare soil dominance (64% cover) on Transect 1 in 2006 (left) to dominance by bluejoint reedgrass (*Calamagrostis canadensis*; 31%), common horsetail (*Equisetum arvense*; 11%), and tall fireweed (*Epilobium angustifolium*; 10%) in 2008 (right).

Figure 3.16: Conversion from bare soil dominance (67% cover) on Transect 2 in 2006 (left) to dominance by bluejoint reedgrass (*Calamagrostis canadensis*; 43%) and common horsetail (*Equisetum arvense*; 20%) in 2008 (right).

Figure 3.17. Two (of the 20) quadrat frames (20 by 50 cm) along Transect 2. In both cases, vegetation cover is sparse in 2006 (left) but well represented in 2008 (right). Dominant species in 2008 in frame 1 (top) are bluejoint reedgrass (*Calamagrostis canadensis*; 85% cover) and common horsetail (*Equisetum arvense*; 60%) and in frame 19 (bottom) are bluejoint reedgrass (15%), common horsetail (15%), and fowl bluegrass (*Poa palustris*; 15%).

Figure 3.18: Bare soil plus course fragments dominate Transect 3 in both 2006 on the left photo (95% cover) and 2008 on the right photo (97%). No plant species has ≥ 5% average cover along the transect in either year. Note: the quadrat frames are "read" along the left side of transect. Vegetation along the stream edge includes plantings by the Youth Restoration Corps. It is anticipated that cover from these plantings will eventually cross the line of the transect.

Figure 3.19: Transect 4 is the "control" on a historic mine tailing. Vascular plant cover is low in both 2006 on the left photo and 2008 on the right photo (8 and 15%, respectively). The most visible plant along the transect in the two photos is tall fireweed (*Epilobium angustifolium*). Perhaps the largest change is that a black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) had fallen across the transect in 2008 (visible in photo).

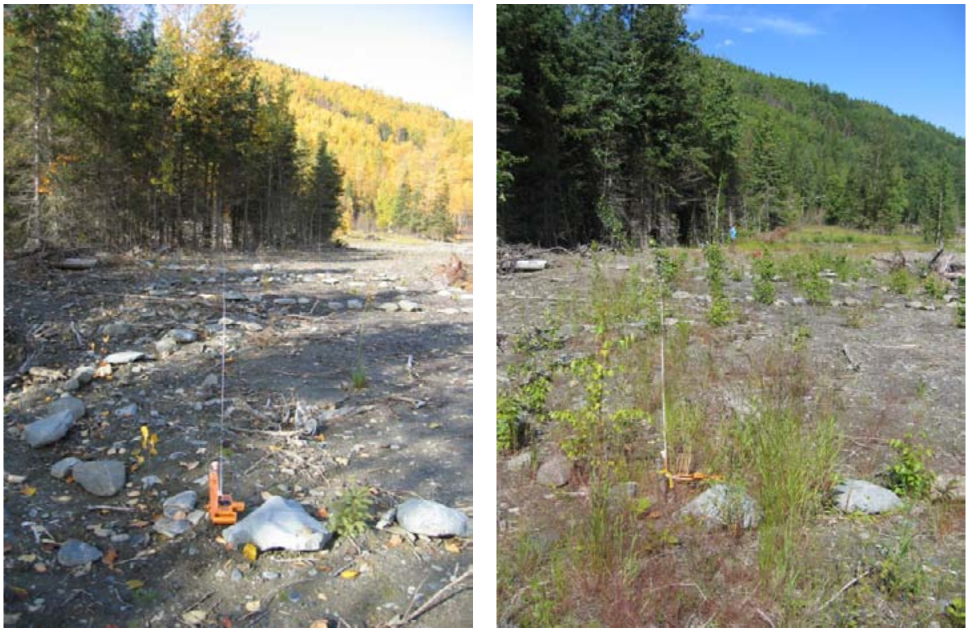


Figure 3.20: Bare soil cover declined from 63% in 2006 to 40% in 2008 on Transect 5 while the dominant plant species, tickle grass (*Agrostis scabra*), increased from a trace in 2006 to 8% cover in 2008. The young trees shown include paper birch (*Betula papyrifera*) and white spruce (*Picea glauca*) planted by the Youth Restoration Corps.

Figure 3.21: Conversion from bare soil dominance (55% cover) on Transect 6 in 2006 to dominance by tickle grass (*Agrostis scabra*; 50%), common horsetail (*Equisetum arvense*; 10%), and bluejoint reedgrass (*Calamagrostis canadensis*; 8%) in 2008.

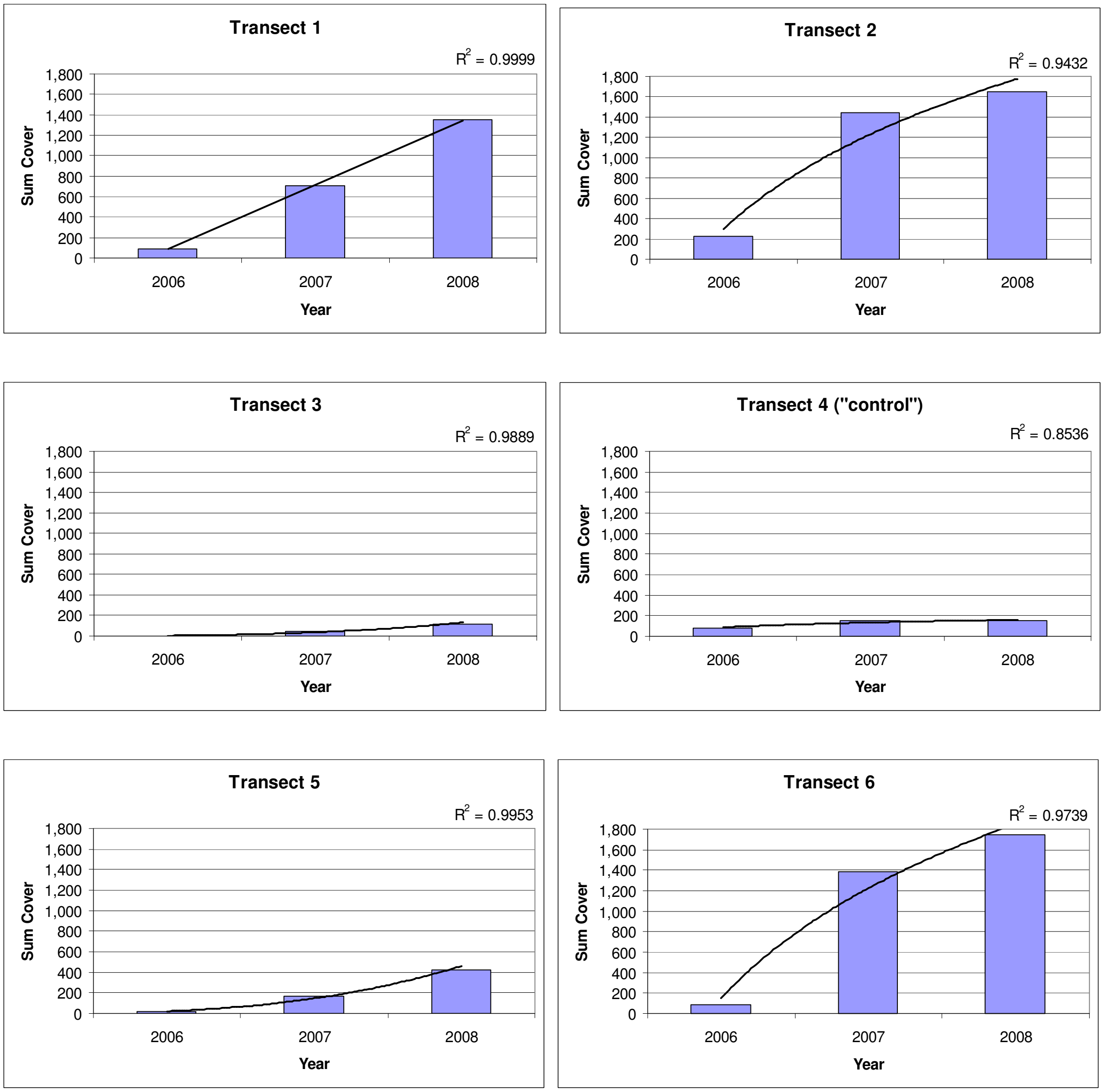


Figure 3.22: Trends in the sum cover of vascular plant taxa by year on the six transects. The trend lines shown fit a linear function (Transect 1), logarithmic functions (Transects 2, 4, and 6), and power functions (Transects 3 and 5).

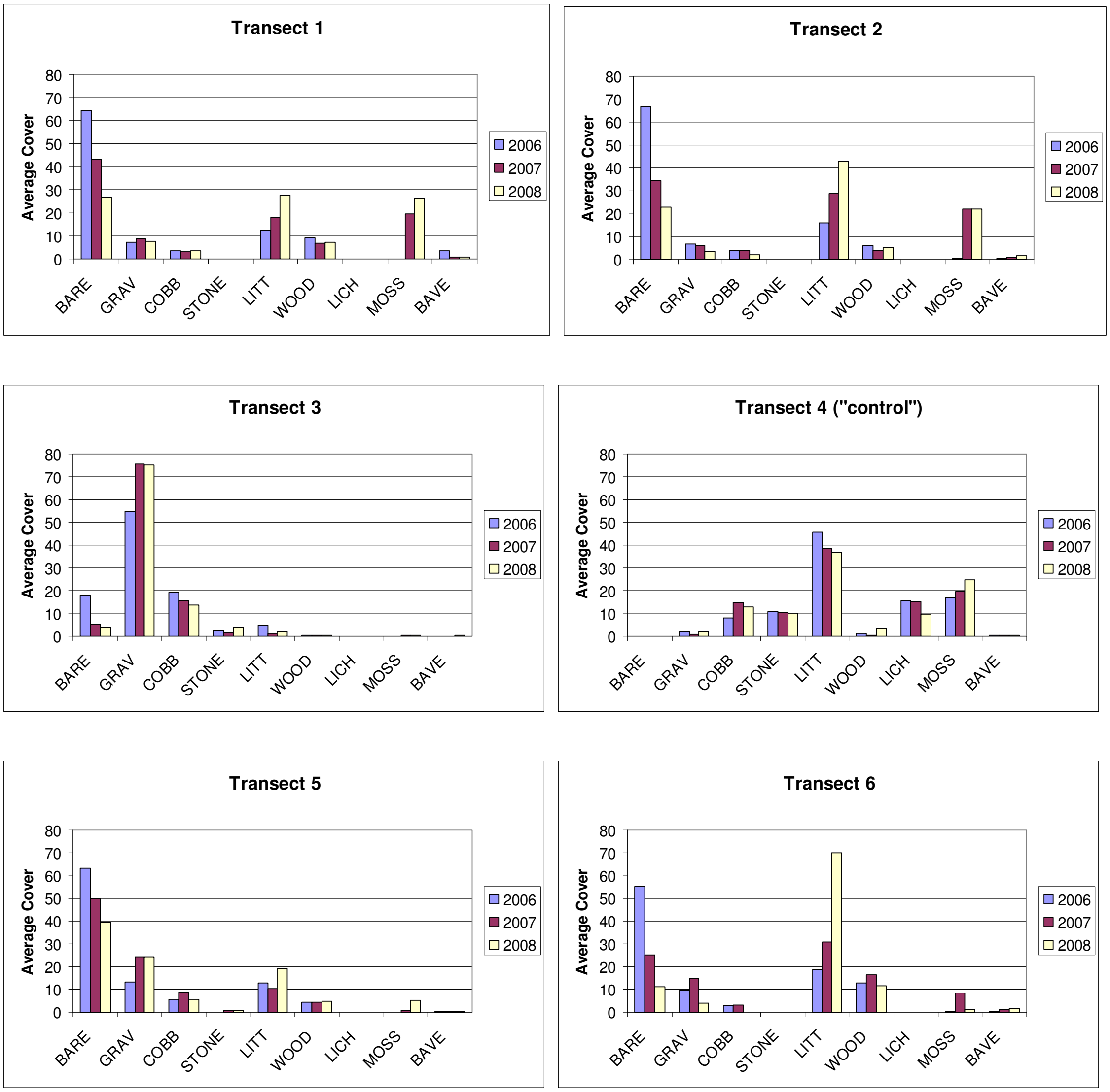


Figure 3.23: Sum cover of ground cover classes by year on the six transects. BARE = bare soil (<2 mm); GRAV = gravel (2 - 75 mm); COBB = cobble (75 - 250 mm); STONE = stone (>250 mm); LITT = litter; WOOD = wood (>13 mm); LICH = lichen; MOSS = moss; and BAVE = basal vegetation.

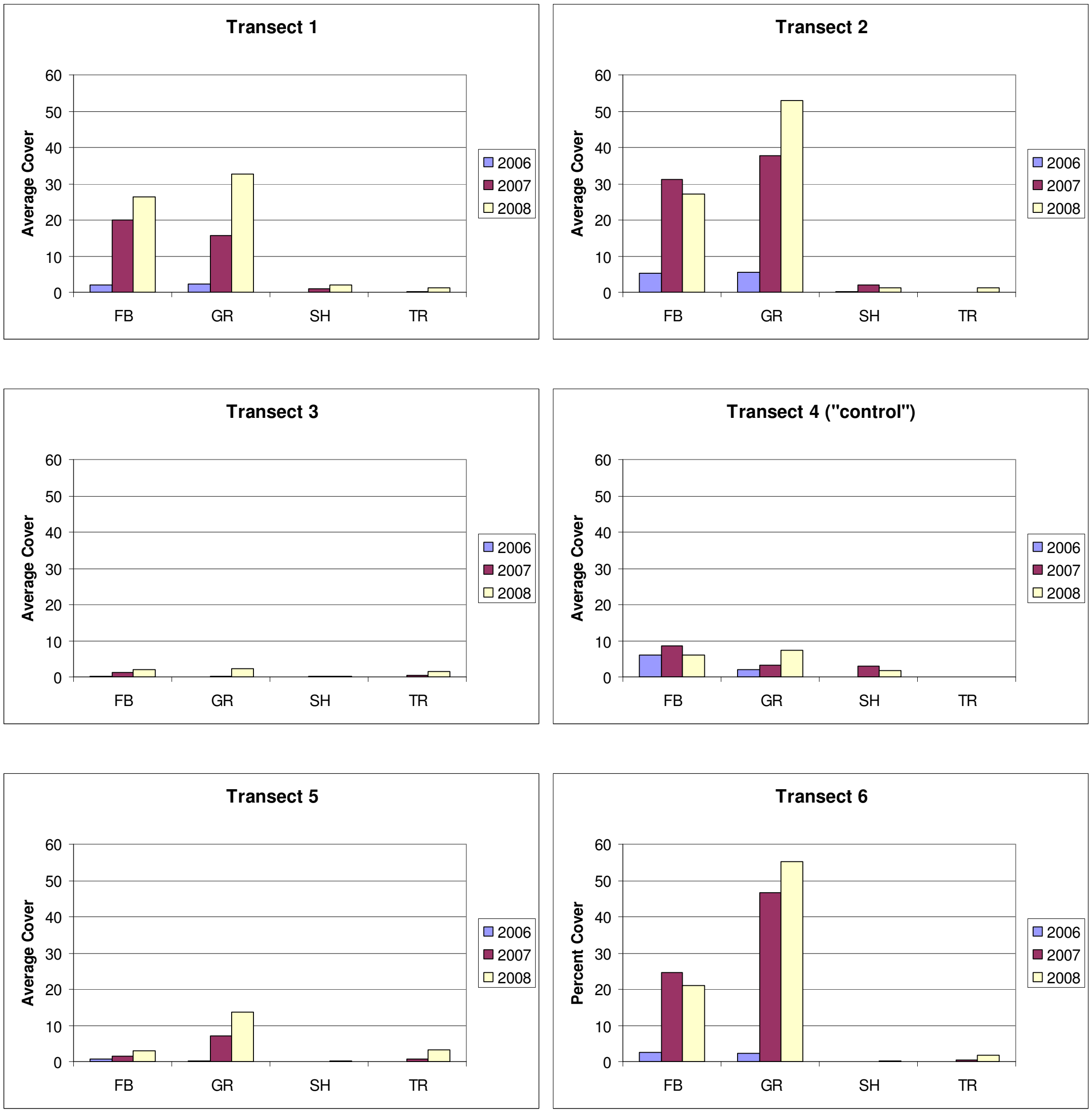


Figure 3.24: Sum cover of life form classes by year on the six transects. FB = forb; GR = graminoid; SH = shrub; and TR = tree.

4 EVALUATION OF PHOTO POINTS

A total of 55 photo points were established throughout the Resurrection Creek project area at different times between 2005 and 2007. Most of these are described in previous monitoring reports (MacFarlane, 2006; MacFarlane, 2007). Of the 55 photo points, 20 have been discontinued because of poor fields of view or changes that occurred during construction. A total of 35 photo points remain, and more than 1 photo is taken at some of these photo point locations.

Photos were taken at these photo points periodically during restoration implementation and in the 2 years following completion of the project in order to characterize changes in channel morphology and floodplain vegetation and provide a continuous record of the response of the ecosystem to restoration. Photos were taken with a Canon Powershot A520 digital camera. "Reference" photos were utilized to duplicate the field of view in each repeat photo.

Locations of photo points are shown in **figure 4.1**, and descriptions of each photo point are presented in **table 4.1**. **Figure 4.2** through **figure 4.40** show pairs of reference photos taken at each photo point in 2006 and 2008. These photo pairs demonstrate the changes that have taken place throughout the project reach in the two years since project completion. The predominant change that has occurred at most photo points is the growth of vegetation. Vegetation growth varies by location, depending on the quality of soil spread on the floodplains. Because no large flood flows have occurred between 2006 and 2008, few large scale channel changes can be seen in the photo point pairs. However, the photo points do not show many of the smaller scale channel changes that have occurred. These photo points will continue to be monitored over the next 6 years and beyond to show long term changes in the channel, floodplain, and riparian vegetation.

Table 4.1: Descriptions of photo point locations along Resurrection Creek.

Photo Point	**Location Description** (PP=Photo Point; u/s=upstream; d/s=downstream)
3	From tailings pile 20ft west of Res Pass Trail, 2190ft u/s of Paystreke Bridge, at lower end of Meander 3. Includes 3a, 3b, 3c, and panorama.
4	From tailings pile 20ft west of Res Pass Trail, 2040ft u/s of Paystreke Bridge, 150ft d/s of PP 3, at Meander 2-3. Includes 4a, 4b, and panorama.
5	From tailings pile 24ft west of Res Pass Trail, 1710ft u/s of Paystreke Bridge, 330ft d/s of PP 4, at Meander 2. Includes 5a, 5b, and panorama.
6b	From tailings pile 20ft west of Res Pass Trail, 1440ft u/s of Paystreke Bridge, 270ft d/s of PP 5, at Meander 1-2.
9	From steep hillslope above and 30ft east of east-side road, 2070 ft u/s of USFS boundary, view u/s.
10	From lower hillside 1800ft u/s of USFS boundary, 270ft d/s of PP9, Meander 4, view upstrm (10a) & dnstrm (10b).
14	From lower hillside just downhill from SRD 3142 BM, on 1.5ft-diam stump, Meander 3-4, view across (14a) and upstream (14b).
15	From flat surface on upstream side of large pointy boulder on left bank at Meander 2. Includes 15a (downstream), 15b (upstream), 15a-panorama, and 15b-panorama.
16	From hillside just west of Res Pass Trail, 600ft u/s of PP3, through gap in trees, at SRD3137 BM, view east.
17	From cut bank on left bank of Meander 4, by spruce stump. Includes 17a (downstream) and 17b (upstream).
19	From bench just below Res Pass Trail, near side channel entrance of Meander 2, view upstream.
20	From tailings pile west of Res Pass Trail, view downstream over downstream half of Meander 2.
21	From high terrace just east of Res Pass Trail, at apex of Meander 3, view upstream through gap in cottonwoods.
22	From tailings pile west of Res Pass Trail, under cottonwood grove, view across over lower Meander 3. Includes 22 and panorama to left.
24	From log jam on right bank of Meander 5, on point between side channel entrance & main channel, at base of birch tree. Includes 24a, 24b, and panorama.
25	From point bar on right bank at downstream end of Meander 5, on boulder just right of first tree, by cross vein structure. Includes 25a, 25b, and panorama.
26	From hillside 30ft east of Res Pass Trail at edge of cleared area, 30ft up-valley from edge of trees, view across river and downstream.
27	At station 38+50, in alders on left bank, looking up steep lower Meander 5 riffle. Includes 27 and panorama.
29	On high left bank terrace across from Upper Split Channel, 15-20 feet above water, looking across. Includes 29a, 29b, 29c, and panorama.
30	On high left bank terrace across from entrance to Upper Split Channel, on small bench, looking across. Includes 30a, 30b, 30c, and panorama.
31	From just west of mining camp, east of Palmer Creek at steep riffle, looking west across Palmer Creek.
33	From 20 ft east of road, 150 ft downstream from mining camp, looking west-northwest, in small clearing of trees.
36	From right bank at Meander 5, near top of upper riffle, by furthest downstream spruce tree, looking northwest.
40	On downstream end of Upper Split Channel Island, looking upstream.
41	From edge of logjam upstream of Meander 3, looking up Meander 4 east side channel.
42	At right pin of Res Creek XS15+38 looking downstream toward Meander 2. Includes 42 and panorama.
43	Looking upstream from end of Meander 3 east Side Channel, from upstream end of Meander 2 logjam.
45	Right bank Meander 5, 50ft upstream of Meander 5 logjam, looking downstream toward steep riffle.
46	Left bank at Meander 5, at station 40+20, 15ft from bankfull bank, looking downstream at lower Meander 5 riffle.
50	From top of logjam at Palmer Creek outlet on right bank, looking upstream.
51	From left bank of Palmer Creek just downstream of pond looking upstream at steep section.
52	From right bank of Channel 1at steep section, looking upstream and downstream (panorama only).
53	Along right side of Channel 1 at station 2+30, about 30 feet up hill from bank, on uphill side of dead spruce, looking downstream.
54	From right pin of Channel 1 XS 5+55, looking downstream.
55	From left bank of Res Cr, across from Palmer Creek confluence, by Meander 4 west side channel inlet, looking across. Includes 55 and panorama.

Figure 4.1: Resurrection Creek photo point locations, updated 2008.

Figure 4.2: Resurrection Creek Photo Point 3 (panorama). This shows the point bar of Meander 3. In the two years since project completion, abundant vegetation has grown on the floodplain, and beavers have removed several cottonwood trees along the trail. Sediment deposition has occurred on the point bar (center of photo), and additional trees have lodged into the logjam (lower left of photo).

Figure 4.3: Resurrection Creek Photo Point 4 (panorama). This shows the western side channel and pond between Meander 2 and Meander 3. Abundant vegetation has grown on the floodplain. Little or no change has occurred on the logjam (right side of photo) or side channel (foreground).

Figure 4.4: Resurrection Creek Photo Point 5 (panorama), showing Meander 2. Abundant vegetation has grown on the floodplains from both re-vegetation and natural regeneration. Spruce trees in the lower right of the photo have died.

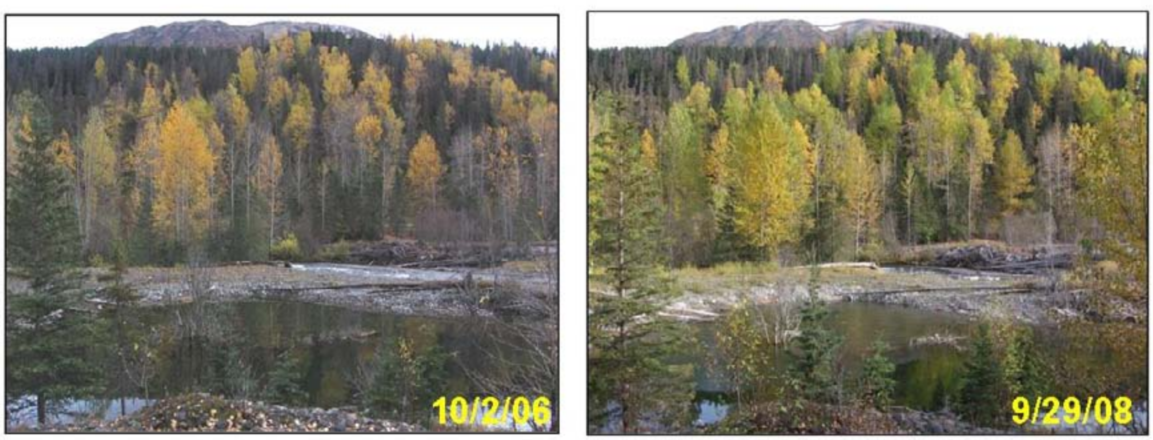


Figure 4.5: Resurrection Creek Photo Point 6b. This shows the west side channel pond of Meander 2. The water surface elevation of the pond varies with flow because the pond drains through the substrate of the outlet (both of these photos were taken at low flow). Abundant vegetation has grown on the floodplains from both re-vegetation and natural regeneration.

Figure 4.6: Resurrection Creek Photo Point 9. This shows the riffle-dominated section between Meander 4 and Meander 5. Few major changes are evident in this pair of photos.

Figure 4.7: Resurrection Creek Photo Point 10a. This shows the eastern floodplain at Meander 4, with the Meander 4 east side channel in the foreground. Only sparse vegetation has grown in this area.

Figure 4.8: Resurrection Creek Photo Point 10b. This shows the eastern floodplain and east side channel of Meander 4. Vegetation has become well established in this area through natural and artificial re-vegetation.

Figure 4.9: Resurrection Creek Photo Point 14a. This shows the western floodplain of Meander 4. Because good soil was spread on this floodplain, abundant vegetation has become established in 2 years through natural regeneration. Few channel changes have occurred following completion of the restoration.

Figure 4.10: Resurrection Creek Photo Point 14b. This shows the lower Meander 4 east side channel. Few changes have occurred to this channel, but sparse re-vegetation has occurred. The channel runs dry during low flows (as shown in both photos) because water seeps through the substrate from the pond upstream back into the main channel of Resurrection Creek.

Figure 4.11: Resurrection Creek Photo Point 15a (panorama). This shows the Meander 2 riffle, logjam, and eastern floodplain. Abundant re-vegetation has occurred on the floodplain, including a row of planted willow stakes along the bank. However, soil was not spread far enough to the bank following restoration, leaving a strip of un-vegetated gravel. The steep riffle upstream of the logjam may be headcutting upstream, but this is not yet evident in the photos.

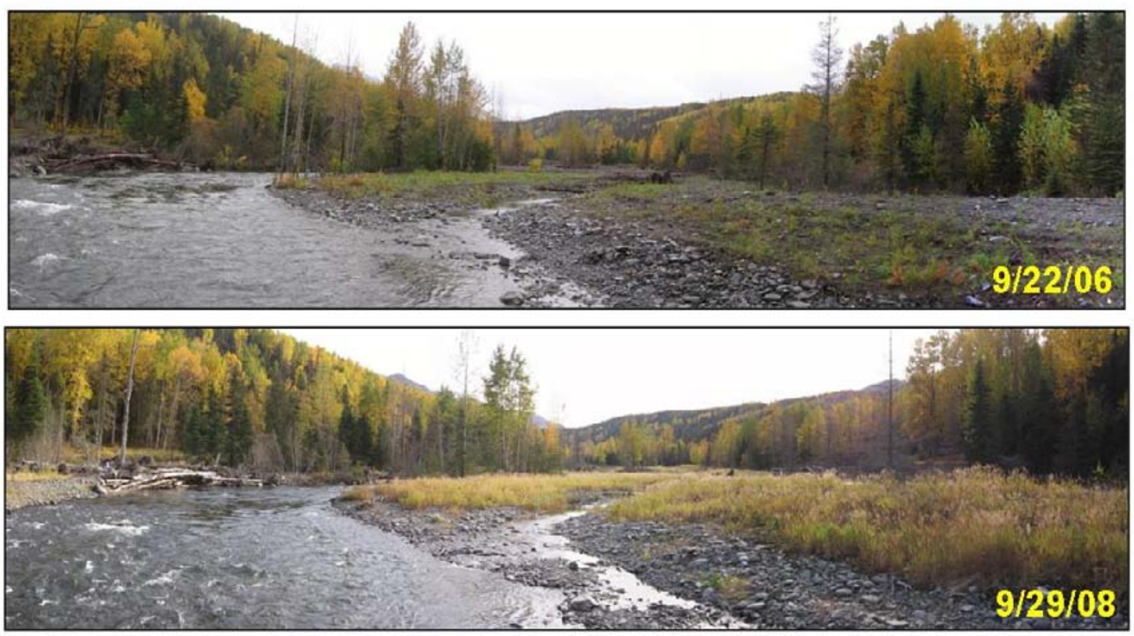


Figure 4.12: Resurrection Creek Photo Point 15b (panorama). This shows the western floodplain between Meander 2 and Meander 3. Abundant vegetation has grown as a result of the natural soils placed on the floodplain. The "meander scar" side channel in the center of the photo carries perennial flow from groundwater.

Figure 4.13: Resurrection Creek Photo Point 16. This shows the western floodplain of Meander 4. Abundant natural regeneration has occurred as a result of the high quality soils spread on the floodplain.

Figure 4.14: Resurrection Creek Photo Point 17a. This shows the Meander 4 pool. Deposition of fine gravels has occurred in the slack water on the right side of the pool.

Figure 4.15: Resurrection Creek Photo Point 17b. This shows the Meander 4 riffle. Few channel changes have occurred.

Figure 4.16: Resurrection Creek Photo Point 19. This shows the western floodplain and side channels between Meander 2 and Meander 3. Abundant natural regeneration has occurred as a result of the high quality soils spread on the floodplain.

Figure 4.17: Resurrection Creek Photo Point 20. This shows Meander 2. Few major channel changes are evident in this photo.

Figure 4.18: Resurrection Creek Photo Point 21. This shows the Meander 3 riffle. Abundant vegetation has grown on the eastern floodplain as a result of re-vegetation and natural regeneration.

Figure 4.19: Resurrection Creek Photo Point 22, showing the lower Meander 3 riffle and logjam. Few channel changes have occurred in this riffle.

Figure 4.20: Resurrection Creek Photo Point 24 (panorama), showing Meander 5. Abundant natural regeneration has occurred on the western floodplain as a result of the high quality soils spread on the floodplain. The photos shown are at two different flow levels.

Figure 4.21: Resurrection Creek Photo Point 25 (panorama), showing the lower riffle of Meander 5. Although this riffle is one of the steepest in the project reach, no headcutting is evident in the 2 years since project completion. However, the riffle has adjusted to a more uniform slope.

Figure 4.22: Resurrection Creek Photo Point 26, showing the upper portion of Meander 5 and the western floodplain. Abundant natural regeneration has occurred on the western floodplain as a result of the high quality soils spread on the floodplain.

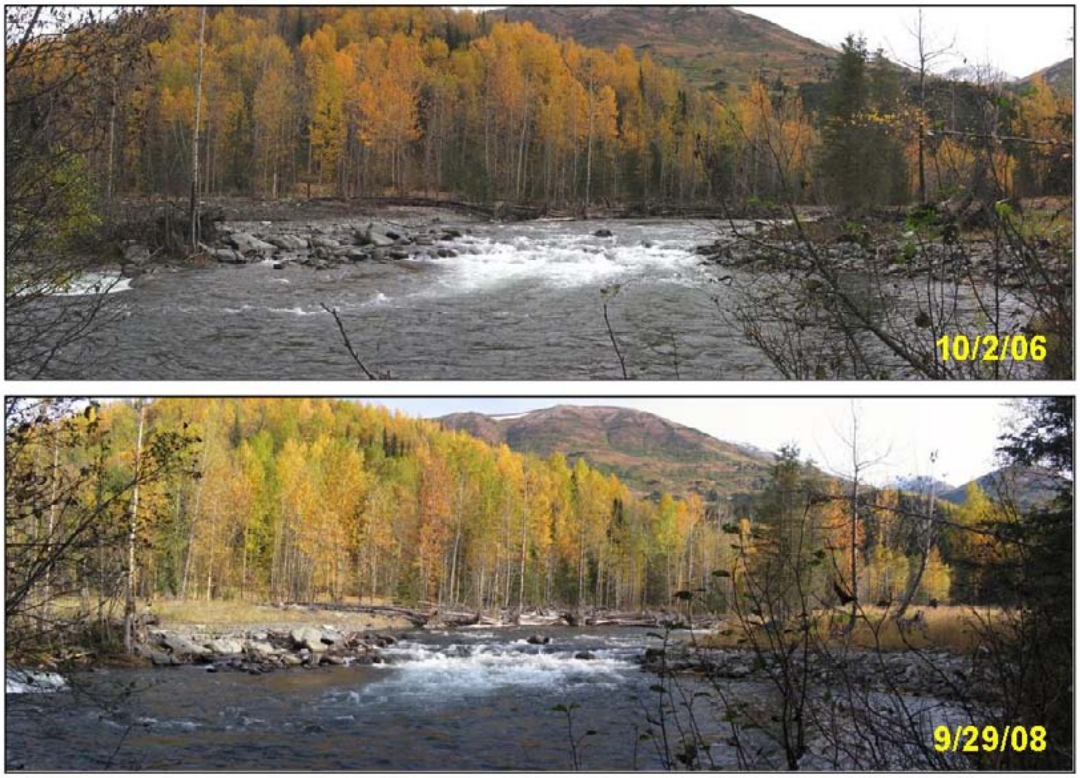


Figure 4.23: Resurrection Creek Photo Point 27 (panorama), showing the lower riffle of Meander 5. Although this riffle is one of the steepest in the project reach, no headcutting is evident in the 2 years since project completion.

Figure 4.24: Resurrection Creek Photo Point 29 (panorama), showing the Upper Reach Split Channel and island. Vegetation growth has occurred where soil was spread on the island.

Figure 4.25: Resurrection Creek Photo Point 30 (panorama), showing the Upper Reach Split Channel and island. Sparse vegetation growth is occurring on the new floodplains because of lack of soil.

Figure 4.26: Resurrection Creek Photo Point 31, showing the steep riffle of Palmer Creek where it joins the Resurrection Creek floodplain. This steep riffle has shown a small amount of adjustment over the 2 years since project completion.

Figure 4.27: Resurrection Creek Photo Point 33, showing the low gradient section of Palmer Creek. Vegetation growth is occurring on the west side of Palmer Creek, but is sparse on the east side. Large scale channel changes have not occurred, but some deposition has occurred along the banks in this low gradient reach.

Figure 4.28: Resurrection Creek Photo Point 36, showing the upper riffle of Meander 5. Vegetation growth is occurring on the western floodplain, but only sparsely on the eastern floodplain as a result of poor soils.

Figure 4.29: Resurrection Creek Photo Point 40, showing the island created by the Upper Reach Split Channel. Moderate re-vegetation is occurring on this new floodplain.

Figure 4.30: Resurrection Creek Photo Point 41, showing the lower portion of the Meander 4 eastern side channel. Little change has occurred since 2006. The channel runs dry much of the year because water seeps through the substrate from the pond upstream back into the main channel of Resurrection Creek.

Figure 4.31: Resurrection Creek Photo Point 42, showing the down-valley view from Meander 3. Since restoration was completed in 2006, more natural re-vegetation has occurred on the west side of the channel than the east side (foreground), because higher quality soils were spread on the east side.

Figure 4.32: Resurrection Creek Photo Point 43, showing the lower portion of the Meander 3 eastern side channel. Little change has occurred since 2006.

Figure 4.33: Resurrection Creek Photo Point 45, showing the lower riffle and logjam of Meander 5. Few major channel changes have occurred at this location.

Figure 4.34: Resurrection Creek Photo Point 46, showing the lower riffle of Meander 5. Abundant natural re-vegetation has occurred on the organic soils spread on the west side of the channel (lower left of photo).

Figure 4.35: Resurrection Creek Photo Point 50, showing the lower riffle of Palmer Creek, just upstream of the confluence. Few channel changes have occurred. Re-vegetation in this area has been slow because of the compacted, clay-rich soils spread following restoration.

Figure 4.36: Resurrection Creek Photo Point 51, showing the steep riffle of Palmer Creek where it drops onto the Resurrection Creek floodplain. It is expected that some future adjustments in slope are occurring and will continue to occur at this riffle because of the steep gradient of the riffle.

Figure 4.37: Resurrection Creek Photo Point 52, showing the upper half of Channel 1. Sparse re-vegetation is occurring amongst the woody debris spread along the banks, but relatively little soil was spread onto these surfaces. Few major channel changes have occurred in Channel 1 because it is designed to spill off excess flows during floods back into the main channel of Resurrection Creek.

Figure 4.38: Resurrection Creek Photo Point 53, showing the upper portion of Channel 1. Sparse re-vegetation is occurring amongst the woody debris spread along the banks, but no major channel changes have occurred.

Figure 4.39: Resurrection Creek Photo Point 54, showing the middle portion of Channel 1. Sparse re-vegetation is occurring amongst the woody debris spread along the banks, but no major channel changes have occurred.

Figure 4.40: Resurrection Creek Photo Point 55, showing the outlet of Palmer Creek (left side of photo), the outlet of the Meander 5 east side channel (center), and the inlet to the Meander 4 west side channel (lower center of photo). No channel changes are evident.

5 DISCUSSION / CONCLUSIONS

Stream channel and riparian vegetation monitoring was conducted on the restored reach of Resurrection Creek in 2005, 2006, 2007, and 2008. The monitoring data suggest that the channel, side channels, and floodplains were constructed successfully, leading to full or partial achievement of the restoration objectives established prior to restoration.

Recommendations: Based on quantitative measurements, qualitative descriptions, and photo points, no channel maintenance is needed at this time. The stream channel has been able to maintain the morphology that was designed, including channel dimensions, longitudinal profile, pool characteristics, and logjams. The channel is also able to adjust itself where needed, as the channel was designed to be semi-dynamic.

Although non-native plant species comprise a small fraction (1%) of the vegetation cover at this time, the potential for the spread of non-native plants remains a concern, with 24 non-native species documented in the project area. It is recommended that the Forest Service implements a small annual weed control program in the project area over the next few years to minimize the spread of non-native species until native plants can achieve full ground cover.

Lessons learned: The restoration project has been successful in the short term, and long term success is anticipated as floodplain vegetation matures, streambanks stabilize, and additional habitat features form. However, this monitoring highlights some aspects of the project that could have been implemented better. These include the following:

- Clay-rich soils compacted by equipment could have been tilled prior to project completion to allow for better vegetation growth.
- Soils could have been spread all the way to the bankfull channel elevation to allow for better vegetation growth along the banks.
- Two riffles in the main channel may have been constructed too steep, increasing the risk of headcutting.
- Large woody debris could have been placed more densely in the main channel and on some of the floodplains.
- Side channel inlet structures could have been constructed deeper to capture additional perennial flow during low flow conditions.
- Floodplains could have been constructed flatter to better attenuate flows, although this would have increased the potential for dynamic channel changes.

Monitoring plan: Monitoring is essential for a project of this size to evaluate project success, keep tabs on maintenance needs, and improve future methods and design. A monitoring schedule that includes monitoring at 1, 2, 5, and 8 years following project completion is recommended. Because the channel restoration was completed in 2006, the 2008 monitoring is considered the year-2 monitoring. Additional monitoring is recommended as follows:

- 2009 (Year-3): Monitor vegetation success of vegetation planted in 2007 and 2008, monitor the spread of invasive plants, and monitor photo points (year-3 monitoring recommended because additional revegetation work was implemented in 2007 and 2008).
- 2011 (Year-5): Monitor channel morphology, vegetation plots, vegetation success, and photo points to begin to show long-term changes.
- 2014 (Year-8): Monitor channel morphology, vegetation plots, vegetation success, and photo points to show long-term changes.
- Additional monitoring may be warranted if flooding causes any substantial changes.

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APPENDIX A: 2008 CHANNEL SURVEY DATA

Stream survey abbreviations

LPT / RPT	Left / Right pin top
LPB / RPB	Left / Right pin bottom
LB / RB	Left / Right bank
TLB / TRB	Top of left / right bank
BKF	Bankfull
LEW / REW	Left / Right edge of water
BLB / BRB	Bottom of left / right bank
CH	Channel
TWG	Thalweg
WS	Water Surface

Channel 1: XS 1+05 - Riffle/Run - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	6.44	468.15	LPT
0	6.79	467.8	LPB
2	6.74	467.85	LB
3.5	7.27	467.32	LB
3.8	6.51	468.08	Boulder
5.7	7.56	467.03	BKF ?
5.8	7.77	466.82	LB
7.4	8.4	466.19	LEW
8.1	9.32	465.27	BLB
10	9.32	465.27	CH
12	9.44	465.15	CH
14	9.37	465.22	CH
16	9.24	465.35	CH
18	9.19	465.4	CH
20	9.2	465.39	CH
22	9.27	465.32	CH
24	9.22	465.37	CH
26	8.99	465.6	CH
28	9	465.59	CH
30	8.95	465.64	CH
32.1	8.94	465.65	BRB
32.5	8.47	466.12	REW
33.4	7.96	466.63	RB
34.4	7.62	466.97	BKF ?
35.5	6.5	468.09	RB
36.8	5.39	469.2	RPB
36.8	4.89	469.7	RPT

Channel 1: XS 4+33 - Riffle - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	7.78	468.88	LPT
0	8.19	468.47	LPB
2	8.46	468.2	LB
5	9.2	467.46	LB
8	10.02	466.64	LB
12	10.82	465.84	LB
15	11.71	464.95	LB
17	12.11	464.55	LB
18.5	12.59	464.07	Willow planting hole
20	12.61	464.05	LB
20.5	12.73	463.93	TLB
20.6	13.01	463.65	BKF ?
21.1	13.35	463.31	LB
21.8	13.78	462.88	LEW
23	14.15	462.51	CH
24.5	14.75	461.91	CH
25.8	14.78	461.88	CH
27.5	15.02	461.64	CH
29	14.9	461.76	CH
31	15.03	461.63	CH
32.5	14.88	461.78	CH
33.7	14.47	462.19	CH
35	14.85	461.81	CH
37	14.81	461.85	CH
39	14.91	461.75	CH
41	14.78	461.88	CH
43	14.63	462.03	CH
45	14.51	462.15	CH
47	14.24	462.42	CH
49	14.1	462.56	CH
51	13.95	462.71	CH
52	14.01	462.65	CH
53.1	13.85	462.81	REW
54	13.64	463.02	RB
54.3	12.78	463.88	Boulder
55.7	12.49	464.17	Boulder
56	13.22	463.44	Gravel
57	13.15	463.51	Willow planting
59	13.11	463.55	Willow planting
60	12.58	464.08	RB
62	12.12	464.54	RB
65	11.45	465.21	RB
69	11	465.66	RB
73	10.44	466.22	RB
77	10.14	466.52	RB
81	8.7	467.96	RB
86	7.41	469.25	RB
88	7.68	468.98	RB
92	6.63	470.03	RPB
92	6.31	470.35	RPT

Channel 1: XS 7+07 - Pool - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	5.91	462.07	LPT
0	6.34	461.64	LPB
3	6.6	461.38	LB
7	7.15	460.83	LB
11	7.76	460.22	LB
14	8.35	459.63	LB
16	8.88	459.1	LB
19	9.3	458.68	LB
21	9.82	458.16	LB
21.5	10.03	457.95	BKF
23	10.41	457.57	LB
24.2	10.69	457.29	LB
26	10.95	457.03	LEW
26.5	11.01	456.97	Backwater
27.5	10.99	456.99	Backwater
28.3	10.92	457.06	Sand Bar
29	10.78	457.2	Sand Bar
29.8	10.81	457.17	Sand Bar
30.8	10.92	457.06	WS
32	11.27	456.71	CH
34	11.83	456.15	CH
36	13	454.98	CH
38	13.26	454.72	CH
40	13.72	454.26	CH
42	14.08	453.9	CH
44	14.15	453.83	CH
46	13.71	454.27	CH
48	13.28	454.7	CH
50	13.33	454.65	CH
52	12.7	455.28	CH
54	11.85	456.13	CH
54.6	11.76	456.22	CH
55	11.59	456.39	CH
56	11.46	456.52	CH
57	11.05	456.93	CH
58.6	10.92	457.06	REW
59	8.4	459.58	Log
60	8.43	459.55	Log
61	8.49	459.49	RB
63	8.36	459.62	RB
66	9.15	458.83	RB
70	8.58	459.4	RB
73	8.21	459.77	RB
75	7.67	460.31	RB
77	8.24	459.74	RB
81.6	7.89	460.09	RPB
81.6	7.52	460.46	RPT

Channel 1: XS 5+55 - Glide - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	6.54	467.51	LPT
0	6.91	467.14	LPB
2	7.57	466.48	LB
5	8.14	465.91	LB
8	8.89	465.16	LB
12	9.82	464.23	LB
15	10.51	463.54	LB
18	11.02	463.03	LB
20	11.22	462.83	LB
22	11.92	462.13	LB
24	12.41	461.64	Willow planting hole
25.5	12.48	461.57	Boulder
26.7	12.88	461.17	?BKF?
27	13.1	460.95	Gravel
28	13.23	460.82	Gravel
29	13.56	460.49	LEW
30	13.76	460.29	CH
32	14.16	459.89	CH
33	14.36	459.69	CH
35	14.41	459.64	CH
37	14.58	459.47	CH
39	14.72	459.33	CH
41	14.57	459.48	CH
43	14.64	459.41	CH
45	14.47	459.58	CH
46	14.94	459.11	CH
48	14.83	459.22	CH
49.5	14.78	459.27	CH
51	14.45	459.6	CH
52	14.12	459.93	CH
53.6	13.56	460.49	REW
55	12.76	461.29	BKF
56	11.7	462.35	TRB
59.4	10.59	463.46	RB (under logjam)
63	10.21	463.84	RB
65	9.31	464.74	RB
69	8.48	465.57	RB
72	7.77	466.28	RB
74.8	7.12	466.93	RPB
74.8	6.65	467.4	RPT

Channel 1 Pebble Counts: 8-27-08

Size Class (mm)	XS1+05 Bankfull Channel	XS1+05 Active Channel	XS4+33 Bankfull Channel	XS4+33 Active Channel	XS5+55 Bankfull Channel	XS5+55 Active Channel
0 - 0.062	2	0	0	0	0	0
0.062 - 0.125	0	0	0	0	0	0
0.125 - 0.25	0	0	0	0	0	0
0.25 - 0.50	1	0	1	1	0	0
0.50 - 1.0	1	1	0	0	1	1
1.0 - 2.0	2	2	1	1	0	0
2.0 - 4.0	1	1	2	1	3	3
4.0 - 5.7	2	2	0	0	4	4
5.7 - 8.0	3	3	1	1	3	3
8.0 - 11.3	1	1	3	3	7	7
11.3 - 16.0	5	5	2	2	2	2
16.0 - 22.6	6	6	3	3	8	8
22.6 - 32.0	9	9	4	4	20	20
32 - 45	16	16	14	14	17	17
45 - 64	20	20	14	13	4	4
64 - 90	22	22	8	8	10	9
90 - 128	8	7	11	11	8	7
128 - 180	0	0	12	12	9	9
180 - 256	1	1	14	14	3	2
256 - 362	1	1	10	9	5	4
362 - 512	2	2	2	2	0	0
512 - 1024	1	1	2	1	0	0
1024 - 2048	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
D16 (mm)	15	17	31	32	11	10
D35 (mm)	35	36	52	52	27	26
D50 (mm)	48	49	87	87	35	34
D84 (mm)	86	85	242	234	130	123
D95 (mm)	127	128	349	338	251	218
D100 (mm)	1024	1024	1024	1024	362	362
Total Particles	104	100	104	100	104	100

Palmer Creek: XS1+46 - Riffle - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	5.36	100.5	LPT
0	5.96	99.9	LPB
2	6.1	99.76	LB
5	6.49	99.37	LB
8	8.6	97.26	LB
12	8.89	96.97	LB
15	8.55	97.31	LB
18	8.87	96.99	LB
19	8.78	97.08	LB
20	9.89	95.97	LB
21.5	9.41	96.45	LB
22.5	10.61	95.25	BKF? High water indicator-debris
23.5	10.98	94.88	LB
24.5	11.18	94.68	LB
25.5	11.52	94.34	LEW
27.6	11.89	93.97	CH
28.5	12.36	93.5	CH
31	12.14	93.72	CH
33	12.11	93.75	CH
35	12.35	93.51	CH
36.5	12.08	93.78	CH
39	12.09	93.77	CH
41	11.77	94.09	CH
43	11.84	94.02	CH
45.6	11.34	94.52	CH- behind big boulder
47	11.81	94.05	CH- behind big boulder
49	11.82	94.04	CH- behind big boulder
51	12.1	93.76	CH- behind big boulder
53	12.19	93.67	CH- behind big boulder
55	12.68	93.18	CH
57	13.16	92.7	CH
59	13.59	92.27	CH
61	13.58	92.28	CH
63	12.63	93.23	CH
65	12.87	92.99	CH
67	12.1	93.76	CH
68.4	11.56	94.3	REW
69.4	11.29	94.57	RB
71	10.95	94.91	RB
74	10.39	95.47	RB
77	10.4	95.46	RB
81	9.78	96.08	RB
88	10.13	95.73	RB
97	9.83	96.03	RB
107	9.05	96.81	RB
117	9.07	96.79	RB
127	9.02	96.84	RPB
127	8.34	97.52	RPT

Palmer Creek: XS3+61 - Glide - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	7.13	95.65	LPT
0	7.78	95	LPB
3	7.9	94.88	LB
8	7.88	94.9	LB
12	8.21	94.57	LB
16	8.17	94.61	LB
21	8.65	94.13	LB
26	9.09	93.69	LB
29	9.51	93.27	BKF - High water indicator
29.3	9.75	93.03	LB
31	9.96	92.82	Willow planting site
33	10.37	92.41	LB
35	10.72	92.06	LB
36.2	11.05	91.73	LEW
37	11.24	91.54	Backwater
38	11.05	91.73	Sand bar
39.2	10.78	92	Sand bar
40.4	10.94	91.84	Sand bar
41.8	11.14	91.64	WS
44	11.24	91.54	CH
47	11.44	91.34	CH
50	11.82	90.96	CH
53	12.12	90.66	CH
55	12.29	90.49	CH
57	12.5	90.28	CH
59	12.42	90.36	CH
61	12.33	90.45	CH
64	12.33	90.45	CH
66	12.37	90.41	CH
69	12.42	90.36	CH
72	12.28	90.5	CH
75	12.14	90.64	CH
78	11.77	91.01	CH
81	11.71	91.07	CH
83	11.52	91.26	Muck
85	11.33	91.45	Muck
87	11.13	91.65	REW
88.1	11.01	91.77	Silt bar
90	10.54	92.24	RB
90.5	10.45	92.33	High water indicator
91.5	10.18	92.6	RB
94	9.24	93.54	RB
97	8.64	94.14	RB
101	7.78	95	RB
106	6.6	96.18	RB
112	5.93	96.85	RPB
112	5.72	97.06	RPT

Palmer Creek: XS5+21 - Riffle - Surveyed 8-27-08

Dist (ft)	FS (ft)	Elev (ft)	Notes
0	5.59	96.49	LPT
0	5.75	96.33	LPB
2	6.08	96	LB
3.5	5.96	96.12	LB
6	6.54	95.54	LB
9	7.49	94.59	LB
12	8.11	93.97	LB
14	8.99	93.09	LB
17	9.79	92.29	LB
18	9.93	92.15	High water indicator
19	10.24	91.84	LB
20.6	10.9	91.18	LEW
22	11.53	90.55	CH
24	11.69	90.39	CH
26	12.15	89.93	CH
28	12.4	89.68	CH
30	12.2	89.88	CH
32	12.1	89.98	CH
34	12.25	89.83	CH
36	12.35	89.73	CH
38	12.24	89.84	CH
40	12.15	89.93	CH
42	11.91	90.17	CH
44	11.67	90.41	CH
46	11.61	90.47	CH
48	11.34	90.74	CH
50.5	11.05	91.03	REW
52	10.84	91.24	Sand bar
54	10.61	91.47	Sand bar
56.4	10.13	91.95	Top of sand bar, high water indic.
58	9.77	92.31	BKF ?
60	9.18	92.9	RB
62	8.62	93.46	RB
68	6.83	95.25	RB
72	5.93	96.15	RB
78.5	5.56	96.52	RPB
78.5	5.05	97.03	RPT

Palmer Creek Pebble Counts: 8-27-08

Size Class (mm)	XS1+46 Bankfull Channel	XS1+46 Active Channel	XS3+61 Bankfull Channel	XS3+61 Active Channel	XS5+21 Bankfull Channel	XS5+21 Active Channel
0 - 0.062	0	0	0	0	1	1
0.062 - 0.125	0	0	0	0	0	0
0.125 - 0.25	0	0	6	6	1	1
0.25 - 0.50	0	0	3	3	3	3
0.50 - 1.0	0	0	2	2	2	2
1.0 - 2.0	0	0	6	6	2	2
2.0 - 4.0	0	0	4	4	3	3
4.0 - 5.7	0	0	5	5	1	1
5.7 - 8.0	0	0	4	4	0	0
8.0 - 11.3	2	2	8	8	2	2
11.3 - 16.0	1	1	2	1	7	6
16.0 - 22.6	4	4	15	15	8	8
22.6 - 32.0	5	5	15	15	13	11
32 - 45	13	13	11	10	14	14
45 - 64	14	14	8	8	11	11
64 - 90	7	5	5	5	11	11
90 - 128	21	19	5	4	15	15
128 - 180	12	12	3	2	6	5
180 - 256	9	9	1	1	2	2
256 - 362	9	9	1	1	2	2
362 - 512	5	5	0	0	0	0
512 - 1024	2	2	0	0	0	0
1024 - 2048	0	0	0	0	0	0
Bedrock	0	0	0	0	0	0
D16 (mm)	37	36	2	2	12	12
D35 (mm)	60	59	11	10	27	28
D50 (mm)	101	102	21	21	40	41
D84 (mm)	251	256	60	57	111	110
D95 (mm)	416	422	127	119	170	170
D100 (mm)	1024	1024	362	362	362	362
Total Particles	104	100	104	100	104	100